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Volume I describes and evaluates new standards to limit radiation doses to the general public and quantities of long-lived radioactive materials in the general environment attributable to planned releases from operations contributing to the generation of electrical power through the uranium fuel cycle. These standards apply to milling, chemical conversion, isotopic enrichment, fuel fabrication, light-water-cooled reactors, and fuel reprocessing, but exclude mining, the transportation of radioactive materials in connection with any of these operations, and waste management operations. The standards specifically limit irreversible contamination due to releases of radioactive krypton, iodine 129, and alpha-emitting transuranics. The total reduction in potential health impact attributable to operations through the year 2000 is estimated to be in excess of 1000 cases of cancer, leukemia, and serious genetic effects in human populations. In addition maximum annual radiation doses are limited to 25 millirems to the whole body and all other organs except the thyroid, which would be limited to 75 millirems.

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ENVIRONMENTAL RADIATION PROTECTION REQUIREMENTS FOR NORMAL OPERATIONS OF ACTIVITIES IN THE URANIUM FUEL CYCLE

FINAL ENVIRONMENTAL STATEMENT

VOLUME I

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Radiation Programs

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VOLUME I

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FINAL ENVIRONMENTAL STATEMENT

ENVIRONMENTAL RADIATION PROTECTION REQUIREMENTS FOR NORMAL OPERATIONS OF ACTIVITIES IN THE URANIUM FUEL CYCLE

Prepared by the

OFFICE OF RADIATION PROGRAMS

Approved by

W. D. Rowe

Deputy Assistant Administrator for Radiation Programs

November 1, 1976

SUMMARY

( ) Draft
(X) Final Environmental Statement

Environmental Protection Agency
Office of Radiation Programs

1. This action is administrative.

2. The Environmental Protection Agency is promulgating standards to limit radiation doses to the general public and quantities of long-lived radioactive materials in the general environment attributable to planned releases from operations contributing to the generation of electrical power through the uranium fuel cycle. These standards apply to most operations within the fuel cycle, including the operations of milling, conversion, enrichment, fuel fabrication, light-water-cooled reactors, and fuel reprocessing, but exclude mining, the transportation of radioactive materials in connection with any of these operations, and waste management operations. Covered operations may occur in any State, although milling operations are expected to occur primarily in Wyoming, New Mexico, Texas, Colorado, Utah, and Washington.

3. Summary of environmental impact and adverse effects:

   a. The standards limit irreversible contamination of the local, national and global environment due to releases of radioactive krypton-85 (half-life 10.7 years), iodine-129 (half-life 17 million years), and alpha-emitting transuranics (half-lives 18 years to 2 million years). The total reduction in potential health impact attributable to operations through the year 2000 is estimated to be in excess of 1000 cases of cancer, leukemia, and serious genetic effects in human populations, based upon the assumed achievement of an annual nuclear production of 1000 GW(e)-yr of electrical power by that year.

   b. Maximum annual radiation doses to individual members of the public resulting from fuel cycle operations are limited to 25 millirems to the whole body and all other organs except thyroid, which would be limited to 75 millirems. Previously applicable Federal Radiation Protection Guides for maximum annual dose to individual members of the public are 500 millirems to the whole body and 1500 millirems to the thyroid from all sources of exposure except those due to medical use and natural background. However, most fuel cycle operations are now conducted well within these guides, and the principal impact of the new individual dose limits will be limited to the relatively small populations in the vicinity of mills, conversion, and fabrication facilities.

   c. There are no anticipated adverse environmental effects of these standards.

4. The following alternatives were considered:

   a. No standards.

   b. Modification of the Federal Radiation Protection Guides for maximum annual exposure of members of the public.

   c. Standards for fuel reprocessing operations only.

   d. Standards without a variance for unusual operating situations, and incorporating standards for annual population dose to limit environmental burdens of long-lived radionuclides, instead of limits on the quantities entering the environment.

   e. The proposed standards.

   f. Standards based on a lower level of cost-effectiveness than those proposed.

   g. Standards based on use of "best available" effluent controls.

5. The following Federal agencies have commented on the Draft Environmental Statement:

   Department of Commerce
   Department of Interior
   Energy Research and Development Administration
   Federal Energy Administration
   Nuclear Regulatory Commission
   Tennessee Valley Authority

6. This Final Environmental Statement was made available to the public and the Council on Environmental Quality in November 1976; single copies are available from the Director, Criteria and Standards Division (AW-460), Office of Radiation Programs, U.S. Environmental Protection Agency, 401 M Street, S.W., Washington, D.C. 20460.

CONTENTS

VOLUME ONE

SUMMARY v

I. INTRODUCTION 1

II. THE PROPOSED ACTION 8

III. THE STATUTORY BASIS FOR ENVIRONMENTAL RADIATION STANDARDS 18

IV. RATIONALE FOR THE DERIVATION OF ENVIRONMENTAL RADIATION STANDARDS 21

V. TECHNICAL CONSIDERATIONS FOR THE PROPOSED STANDARDS 29

- A. Model Projections of Fuel Cycle Environmental Impacts 37
- B. Results from Environmental Assessments under NEPA 52
- C. Field Measurements of Environmental Impact 61
- D. The Proposed Standards 68

VI. ANTICIPATED IMPACT OF THE PROPOSED STANDARDS 78

- A. Environmental Impact 79
- B. Health Impact 87
- C. Economic Impact 93
- D. Administrative Impact 96
- E. Intermedia Effects 100
- F. Impact on Facility Distribution and Reactor Mix 102

VII. ALTERNATIVES TO THE PROPOSED ACTION 125

VIII. MAJOR ISSUES RAISED DURING REVIEW 140

A. Implementation of the Standards 140

B. Control of Krypton-85 166

C. Health Effects Estimates 177

REFERENCES 189

APPENDIX A: The Proposed Rule

APPENDIX B: Policy Statement - Relationship Between Radiation Dose and Effect

VOLUME TWO

IX. RESPONSE TO COMMENTS

APPENDIX: Comments on the Draft Statement

TABLES

Table 1. Characteristics of Model Fuel Cycle Facilities 32

Table 2. Principal Radioactive Effluents from the Uranium Fuel Cycle and their Associated Critical Target Organs 36

Table 3 Dose and Quantity Levels Implied by Model Projections 41

Table 4. Environmental Impacts of Normal Releases from Pressurized Water Reactors 54

Table 5. Environmental Impacts of Normal Releases from Boiling Water Reactors 56

Table 6. Environmental Impacts of Normal Releases from Other Fuel Cycle Facilities 58

Table 7. Calculated Doses from Noble Gas Releases at Operating Plants (1972-1974) 63

Table 8. The Proposed Standards 70

Table 9. Potential Incremental Whole Body Doses Due to Overlap of Exposures from Airborne Effluents at Closest Presently Projected Nuclear Facility Sites 76

Table 10. Potential Health Effects Attributable to Operation of the Nuclear Fuel Cycle Through the Year 2000 at Various Environmental Radiation Protection Levels 88

Table 11. Environmental Impacts of Three- and Four-Unit Sites 107

Table 12. Comparison of the Proposed Standards and Alternative Levels of Control for Environmental Releases 138

Table 13. Cost-Effectiveness of Krypton Control at Fuel Reprocessing Plants 171

FIGURES

Figure 1. Uranium Fuel Cycle Facility Relationships 30

Figure 2. Projected Nuclear Fuel Cycle Facility Needs 33

Figure 3. Risk Reduction vs Cost for the Uranium Fuel Cycle 39

Figure 4. Cost-effectiveness of Risk Reduction for the Uranium Fuel Cycle 49

Figure 5. Distribution of Noble Gas Releases from Boiling Water Reactors in 1961-1973 65

Figure 6. Projected Environmental Burden of Tritium from the U.S. Nuclear Power Industry 81

Figure 7. Projected Environmental Burden of Carbon-14 from the U.S. Nuclear Power Industry 82

Figure 8. Projected Environmental Burden of Krypton-85 from the U.S. Nuclear Power Industry for Controls Initiated in Various Years 83

Figure 9. Projected Environmental Burden of Iodine-129 from the U.S. Nuclear Power Industry at Various Levels of Control 84

Figure 10. Projected Environmental Burdens of Alpha-emitting Transuranics with Half-lives Greater than One Year from the U.S. Nuclear Power Industry 85

Figure 11. Cumulative Potential Health Effects Attributable to Environmental Burdens of Long-lived Radionuclides from the U.S. Nuclear Power Industry 92

Figure 12. Risk Reduction vs Cost for Alternatives to the Proposed Standards 139

I. INTRODUCTION

Within the last few years it has become clear that the national effort to develop the technology required to generate electricity using nuclear energy has been successful, and that the generation of electrical power by this means is likely to play an essential role in meeting national electrical power needs during the next several decades (1). However, the projected extensive use of nuclear power has led to widespread public concern over the hazards to health posed by the radioactive materials associated with nuclear power generation. Unlike fossil-fueled power generation, which uses fuels known to man from prehistoric times, the fissioning of nuclear fuel is a very recently discovered phenomenon and man is just beginning to learn how to assess the full implications of its exploitation. Paradoxically it is also true, however, that we know more about the implications for health of radioactive materials than of the pollutants released by the burning of traditional fossil fuels. This knowledge facilitates the process of assessing the implications of using nuclear energy for the generation of electrical power. This is particularly true for planned releases of radioactive materials; the assessment of accidental releases is a much more difficult task which is heavily dependent upon our limited capability to predict the probabilities of accidents. In the process of developing these proposed standards a comprehensive assessment has been made of planned releases of radioactive materials associated with nuclear power generation so as to assure an adequate basis for informed judgments of what the potential effects on public health and the environment are, what can be done to minimize these effects through the promulgation of environmental radiation standards, and the costs involved.

The Environmental Protection Agency was vested with the responsibility for establishing environmental radiation standards through the transfer of authorities from the Atomic Energy Commission (AEC) and the former Federal Radiation Council by the President's Reorganization Plan No. 3 of 1970 (2). The Agency's role is complementary to the responsibilities transferred from the AEC to the Nuclear Regulatory Commission (NRC) in 1975 (3), which are focused on the detailed regulation of individual facilities within the standards established by EPA, whereas EPA must address public health and environmental concerns associated with the fuel cycle taken as a whole.

This statement summarizes the data base and judgments upon which these proposed environmental radiation standards for planned radioactive effluents from the uranium fuel cycle are based. It also provides an assessment of the anticipated impact of the proposed standards and of alternative courses of action on public health, the environment, the industry and upon government. In reviewing the information presented in this statement it should be recognized that past growth of the nuclear power industry has been conducted so that radioactive environmental contamination is minimal at the present time. Because of this situation, an unusual opportunity as well as a challenge exists to manage future growth in the use of nuclear energy in a preventive rather than in a remedial context, a situation that is the ultimate aim of all environmental protection. Within such a context, the tradeoffs between potential health risks or environmental quality and the costs of environmental controls can be made most easily and with the greatest effectiveness.

In the United States the early development of technology for the nuclear generation of electric power has focused around the light-water-cooled nuclear reactor. For this reason the proposed standards and this statement will consider only the use of enriched uranium-235 as fuel for the generation of electricity. There are, in all, three fuels available to commercial nuclear power. These are uranium-235, uranium-233, and plutonium-239. The first of these materials occurs naturally and the last two are produced as by-products in uranium-fueled reactors from the naturally-occurring isotopes thorium-232 and uranium-238, respectively. Although substantial quantities of plutonium-239 are produced from uranium-238 present in the fuel of conventional light-water-cooled reactors, large-scale production requires the development of a commercial breeder reactor. The liquid metal fast breeder, which would make possible the extensive production and utilization of plutonium fuel, is now under intensive development, but is not expected to be commercially available before the late 1980's, at the earliest (4). However, limited commercial use of recycled plutonium produced in light-water-cooled reactors is under consideration for the near future (5). The third fuel, uranium-233 derived from naturally-occurring thorium, is used by a new reactor type also under active development, the high temperature gas-cooled reactor, which may be available for expanded commercial use by the end of this decade.

It has been projected that from approximately 400 to 1500 gigawatts of nuclear electric generating capacity based on the use of uranium fuel will exist in the United States within the next twenty-five years (6). This increase will require a parallel growth in a number of other activities that must exist to support uranium-fueled nuclear reactors. All of these activities together, including the reactor itself, comprise the uranium fuel cycle. This fuel cycle is conveniently considered in three parts. The first consists of the series of operations extending from the time uranium ore leaves the mine face through fabrication of enriched uranium into fuel elements. This is followed by a part consisting only of the power reactor itself, in which the fuel is fissioned to produce heat which in turn is used to generate electric power. The final part consists of fuel reprocessing plants, where used fuel elements are mechanically and chemically broken down to isolate the large quantities of high-level radioactive wastes produced during fission for permanent protective storage and to recover substantial quantities of unused uranium and reactor-produced plutonium.

These three parts have fundamentally different characteristics with respect to radioactive effluents. The first involves only naturally-occurring radioactive materials which are, nevertheless, made available to the biosphere as the direct result of man's activity. The control technologies appropriate to these materials, specifically uranium and its associated daughter products, are common to most components of this part of the cycle. By means of fission and activation the reactor creates large additional quantities of radioactive materials. Although these are largely contained by fuel cladding, some small releases do occur. However, in spite of their relatively low levels, reactor effluents are important because these facilities are the most numerous component of the fuel cycle and are often located close to large population centers in order to achieve economic transmission of the power they produce to its ultimate users. Finally, although fuel reprocessing plants are few in number, they represent the largest single potential source of environmental contamination in the fuel cycle, since it is at this point that the fuel cladding is broken up and all remaining fission and activation products become available for potential release to the environment.

The environmental effects of planned releases of radioactive effluents from the components of this cycle have been analyzed in detail by the EPA in a series of technical reports covering fuel supply facilities, light water reactors, and fuel reprocessing (7,8,9,10). These technical analyses provide assessments of the potential health effects associated with each of the various types of planned releases of radioactivity from each of the various operations of the fuel cycle and of the effectiveness and costs of the controls available to reduce releases of these effluents. In addition to these analyses, there is considerable other information on planned releases from these types of facilities available. This includes the generic findings of the NRC concerning the practicability of effluent controls for light-water-cooled reactors, extensive findings of the utilities, the NRC, and the AEC as reflected by environmental statements for a variety of individual fuel cycle facilities, and finally, the results of a number of detailed environmental surveys conducted by EPA at typical operating facilities.

These standards deal with planned releases only, although it is recognized that the potential hazard from accidents could be substantial. However, since the coupling between controls for planned effluents and the potential for accidents is minimal, it has been concluded that these two important issues can be addressed separately. In addition to the safety issue, there are two other interrelated aspects of nuclear power production that are not addressed by these standards. These are the disposal of radioactive wastes and the decommissioning of facilities. These issues are currently under study by EPA, ERDA, the U.S. Geological Survey, CEQ, NRC, and other government agencies, and EPA expects to make recommendations for criteria and standards in these areas in the future. In any case, the implications of the controls required by this rulemaking for radioactive wastes and for decommissioning represent minor perturbations on already-existing requirements for waste management for the fuel cycle.

II. THE PROPOSED ACTION

These radiation standards for normal operations of the uranium fuel cycle are proposed in order to achieve two principal objectives: 1) to assure protection of members of the public against radiation doses resulting from fuel cycle operations, and 2) to limit the environmental burden of long-lived radioactive materials that may accumulate as a result of the production of electrical energy, so as to limit their long-term impact on both current and future generations. These objectives are proposed to be achieved by standards which would limit: 1) the annual dose equivalent to the whole body or any internal organ, except the thyroid, to 25 millirems, and the annual dose equivalent to the thyroid to 75 millirems; and 2) the quantities of krypton-85, iodine-129, and plutonium and other alpha-emitting transuranic elements with half-lives greater than one year released to the environment per gigawatt-year of electrical power produced by the entire fuel cycle to 50,000 curies, 5 millicuries, and 0.5 millicuries, respectively. The proposed rule is contained in Appendix A.

Standards in the first category are designed primarily to address doses due to short-lived fission-produced materials (although doses from long-lived fission-produced materials are included, they will generally make a small contribution to persons receiving doses approaching these limits for individuals). Those in the second category specifically address long-lived radioactive materials. The standards for environmental burdens of specific long-lived radionuclides are expressed in terms of the quantity of electricity produced in order that society will be assured that the risk which is associated with any long-term environmental burden of these materials is incurred only in return for an associated beneficial product: electrical power. The standard permits up to the specified amounts of these radionuclides to be released at any time or location and at any rate that will not exceed the individual dose limitations. The standards proposed apply to almost all operations within the fuel cycle, including milling, conversion, enrichment, fuel fabrication, light-water-cooled reactors, and fuel reprocessing. Mining operations are excluded, since these standards are proposed under authority of the Atomic Energy Act, which does not extend to effluents from mining operations. A variance is proposed to permit temporary operation in the presence of unusual operating conditions when this is judged to be in the public interest by the responsible regulatory agency. This can occur, for example, due to an emergency need for uninterrupted delivery of power, or in the presence of a temporary and unusual operating situation when a plan to achieve compliance in a timely manner has been approved by the regulatory agency.

The significance of the nuclear power industry to future energy supply and the future public health and environmental implications of continued operation of this industry at currently required levels of effluent control combine to provide a major incentive for the establishment of these environmental radiation standards.

The nuclear power industry is projected by a wide variety of studies to grow from its present proportion of approximately 8 percent of total electric power capacity to between 40 and 60 percent by the year 2000 (an absolute growth from about 40 gigawatts to anywhere from 400 to 1500 gigawatts) (11). It has been estimated that the annual capital investment in current dollars associated with this growth will increase from 6 to 600 billion dollars, and that the value of electric power produced annually will grow from about 6 to over 200 billion dollars during this same period (12).

The development of a large nuclear power industry has, however, the potential for leading to unnecessary exposure of the public to radioactive materials and to irreversible contamination of the environment by persistant radionuclides (13). The implications of this exposure and irreversible contamination are examined in detail below, and include the potential for an unnecessary deleterious impact on public health, both nationally and worldwide. It is important, therefore, to establish now the environmental radiation standards within which this growth will take place.

The principal potential impact of radioactive effluents on the biosphere is the induction of deleterious health effects in man. Comparable levels of impact undoubtedly exist in other biota, but there is no present evidence that there is any biological species whose sensitivity is sufficiently high to warrant a greater level of protection than that adequate for man (14).

Health effects induced in man by radiation doses resulting from exposure to radiation fall into two broad categories - somatic and genetic. The principal somatic effects include leukemias; thyroid, lung, breast, bone, and a variety of other cancers; and, possibly, the impairment of growth and development. It appears clear that sensitivity varies with age, the embryo and young children being particularly sensitive. The range of possible genetic effects encompasses virtually every aspect of man's physical and mental well-being. The major exceptions are infectious diseases and accidents, but even here inherited susceptibilities also play a role (14).

The potential impact of radioactive effluents can be considered from three different perspectives. The first of these is the maximum radiation dose to individuals. This measure has been the one traditionally used for limiting the potential impact of radiation, and existing radiation standards are all related to limits on radiation doses to individuals (15). It is of interest to note that the origin of existing radiation limits for the general population, at least for somatic consequences, has been through taking a somewhat arbitrary fraction (usually 1/10) of the dose limits established for radiation workers exposed under controlled occupational conditions (16). The current Federal Radiation Protection Guides for limiting radiation dose to members of the general public are 500 mrem/yr to the whole body of individuals and 5 rems in 30 years to the gonads for all radiation except that due to medical practice and natural background radiation. Additional Guides exist for some other organs. As an operational procedure, it is recommended that a limit of 170 mrem/yr to the whole body be applied to suitable samples of the population to assure that the first of these limits is satisfied for any individual. This procedure automatically assures that the second limit will also be satisfied (17).

A second perspective is provided by summing the individual annual radiation doses to each of the members of a population to obtain a measure of the total potential annual population impact. This summation may be made directly on doses, rather than on potential health effects, because it is the consensus of current scientific opinion that it is prudent to assume a proportional relationship between radiation doses due to environmental levels of radiation and their effects on health for the purpose of establishing standards to protect public health. Although this sum is usually expressed on an annual basis, it may also be assessed for longer periods, which leads to consideration of a third aspect of the complete assessment of the potential impact of radioactive effluents - the buildup and persistence of long-lived radionuclides.

Much of the radioactivity released from nuclear facilities is short-lived and is essentially removed from the environment by radioactive decay in less than one year. However, a few radioactive materials have greater persistence and decay with half-lives ranging from decades to millions of years. These materials may deliver doses to populations throughout this period as they migrate through the biosphere. The Agency has characterized the sum of these doses as the "environmental dose commitment" (13). It is calculated for a specific release at a specific time and is obtained by summing the doses to populations delivered by that release in each of the years following release to the environment until the material has either decayed to levels at which significant contributions to the sum of doses no longer occur, been permanently removed from the biosphere, or for a more limited period of time, in which case it is necessary to specify that only a partial environmental dose commitment has been calculated. For the purpose of the analyses made for these standards, environmental dose commitments were calculated for a maximum period of 100 years.

There are two other dose commitment concepts in common use. The first is the dose committed to an individual by intake of internal emitters. This dose commitment is directly incorporated into the sum of doses to individuals comprising the environmental dose commitment. The second is the dose commitment used in publications of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (18), which is defined as the infinite time integral of the average dose in a population due to a specific source of exposure. This concept is not, in general, simply relatable to the environmental dose commitment, but in the special case of a population of constant size is equal to the environmental dose commitment divided by the (constant) number of individuals in the population.

In recent years, it has become increasingly clear that the current Federal Radiation Protection Guide (500 mrem/yr to individuals, usually interpreted as an average of 170 mrem/yr to members of critical populations) for limiting radiation doses to the public is unnecessarily high. The National Academy of Sciences, in its recent report to the Agency on the effects of environmental levels of radiation exposure (14), expressed what may be regarded as a consensus of informed scientific opinion when it said:

> There is reason to expect that over the next few decades the dose commitment for all man-made sources of radiation except medical should not exceed more than a few millirems average annual dose. [And further,] ...it appears that [societal] needs can be met with far lower...risk than permitted by the current Radiation Protection Guide. To that extent, the current Guide is unnecessarily high.

The potential impact on health caused by effluents from an expanding nuclear power industry, if it were to operate at the levels permitted by the current Federal Radiation Protection Guides, would be large (14). Current Guides do not, in addition, directly address either the second or the third perspective of radiation exposure described above. However, the Guides are accompanied by the advice that exposures should be kept as far below the Guides for exposure of individuals as "practicable," and major portions of the industry operate at approximately one-tenth of the level permitted by the current Guides. This was accomplished in large part through the implementation of this concept by the former AEC in its licensing of individual facilities.

However, attention to individual exposure alone leads to inadequate control of releases of long-lived radioactive materials, which may give rise to substantial long-term impacts on populations while contributing only small increases to annual individual exposures. In addition, the reduction of individual dose alone, if pursued without consideration of the associated population dose and the economic factors associated with the controls that reduce it, can also lead to the use of unreasonably restrictive control of short-lived radioactive materials that achieves negligible improvement in public health protection for unreasonably large investments in control technology. Reduction of the exposure of individuals to as low as "practicable" levels is therefore not, by itself, an adequate basis for radiation standards.

Most present regulation of the nuclear industry is applied in the form of individual licensing conditions for specific facilities. The AEC has based these regulations on standards derived from the recommendations of a variety of external advisory groups, such as the International Commission of Radiation Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP) and, in recent years, on the Federal guidance provided by the former Federal Radiation Council (FRC). These groups have traditionally focused primarily upon the objective of limiting risk to the individual, although consideration of genetic consequences to entire populations has provided the basis for some general guidance on upper limits for exposure of entire populations. There has, however, been no external source of standards or guidance for radioactive materials from a specifically environmental point of view, such as, for example, from the point of view of limiting the long-term environmental buildup of radionuclides, until the President's Reorganization Plan No. 3 created EPA and charged it with that responsibility.

In summary, present radiation protection guidance, as it applies to the nuclear power industry, requires expansion to satisfy the needs of the times. Specifically:

a. The consideration of dose to man on an annual basis should be expanded to include the long-term impact of the release of long-lived radionuclides to the environment.
b. The Radiation Protection Guides for annual dose to individuals are unnecessarily high for use by the industry.
c. Application of the Radiation Protection Guidance that individual doses should be maintained as far below the Radiation Protection Guides as "practicable" should include

explicit consideration of both the total population exposure and the costs of effluent controls.

The proposed action reflects these three considerations in order to insure that the anticipated major expansion of nuclear power takes place with public assurance of an acceptable level of radiation protection of public health and the environment.

III. THE STATUTORY BASIS FOR ENVIRONMENTAL RADIATION STANDARDS

These standards are proposed under authority of the Atomic Energy Act of 1954, as amended, transferred to the Environmental Protection Agency from the Atomic Energy Commission by the President's Reorganization Plan No. 3 (October, 1970) (2). That plan provided for the transfer of environmental standards functions from AEC to EPA:

> ...to the extent that such functions of the Commission consist of establishing generally applicable environmental standards for the protection of the general environment from radioactive material. As used herein, standards mean limits on radiation exposures or levels, or concentrations or quantities of radioactive material, in the general environment outside the boundaries of locations under the control of persons possessing or using radioactive material.

This authority is distinct from and in addition to the authority to "...advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance to Federal agencies in the formulation of radiation standards..." which was also transferred to EPA from the former Federal Radiation Council by the same reorganization plan. That authority, while it is broad in scope, is most appropriately applied to the issuance of general radiation guidance to Federal agencies and for the use of the States, however, and not to the setting of specific environmental radiation standards. These proposed environmental radiation standards are consistent with and would supplement the protection provided by existing Federal Radiation Protection Guides and Guidance.

Two points are relevant to EPA's authority to set environmental radiation standards. First, although EPA is not limited to specific criteria for setting such standards (e.g., requirements for "best practicable" or "best available" technology, or for effluent levels having "no health effects"), the standards can apply only outside the boundaries of facilities producing radioactive effluents. The required environmental protection can be provided within this constraint. By the same token, this authority may not be used to set limits on the amount of radiation exposure inside these boundaries, consequently regulation of occupational exposures of workers inside the boundary is carried out by the AEC (now the NRC) operating under existing Federal Radiation Protection Guides for occupational exposure.

Secondly, EPA can only set standards; the authority to regulate specific facilities was not transferred by Reorganization Plan No. 3 (2). Application and enforcement of these standards against specific facilities is the responsibility of the NRC. The division of responsibilities between EPA and AEC (whose regulatory responsibilities are now carried out by NRC) for carrying out these objectives was addressed specifically by the President's message transmitting Reorganization Plan No. 3 to the Congress as follows:

> Environmental radiation standards programs. The Atomic Energy Commission is now responsible for establishing environmental radiation standards and emission limits for radioactivity. These standards have been based largely on broad guidelines recommended by the Federal Radiation Council. The Atomic Energy Commission's authority to set standards for the protection of the general environment from radioactive material would be transferred to the Environmental Protection Agency. The functions of the Federal Radiation Council would also be transferred. AEC would retain responsibility for the implementation and enforcement of radiation standards through its licensing authority.

This division of responsibility is not expected to interfere with effective administration and achievement of these proposed environmental standards (see, also, Chapter VI, Section D).

IV. RATIONALE FOR THE DERIVATION OF ENVIRONMENTAL RADIATION STANDARDS

Two objectives are of prime importance in deriving environmental radiation standards for a major activity such as the uranium fuel cycle. The first is that as complete an assessment of the potential impact on public health be made as possible. The second is that the cost and effectiveness of measures available to reduce or eliminate radioactive effluents to the environment be carefully considered. It would be irresponsible to set standards that impose unnecessary health risks on the public (unnecessary in the sense that exposures permitted by the standards can be avoided at a small or reasonable cost to the industry), and it would be equally irresponsible to set standards that impose unreasonable costs on the industry (unreasonable in the sense that control costs imposed by the standards provide little or no health benefit to the public).

Projections of health effects made in the technical analyses for this rulemaking have been based in large part on recommendations resulting from the recently completed study of the effects of low levels of ionizing radiation by the National Academy of Sciences-National Research Council's Advisory Committee on the Biological Effects of

Ionizing Radiation (BEIR Committee) (14). This committee, which consisted of a broad cross-section of prominent members of the U.S. scientific community knowledgeable in the various disciplines appropriate to a review of existing scientific knowledge in this area, has provided EPA with the most exhaustive analysis of risk estimates that has been made to date. Their conclusions include, among others, the recommendations that it is prudent to use a linear, nonthreshold, dose-rate-independent model for establishing standards to limit health effects from environmental levels of radiation, and that numerical standards for the nuclear power industry should be established on the basis of an analysis of the cost-effectiveness of reducing these effects.

Other authorities have suggested, usually on the basis of the same data, that estimates of health effects based on the first of the above recommendations may be either too high or too low. Those supporting the first view argue that (a) risk coefficients have been derived from data obtained at much higher doses and may, therefore, not properly reflect any nonlinearity that may be present at low doses or dose rates and (b) that repair mechanisms may operate at low doses or dose rates to reduce the impact of such exposures. Those supporting the second view argue that: (a) some data indicate that low doses may be more efficient in producing health effects than higher doses, (b) the effect of genetic mutations on overall ill-health is much greater than is commonly assumed, or (c) certain population subgroups have a predisposition to radiation-induced cancer and are, therefore, at greater risk than most studies have indicated.

The NAS committee examined all of these views in some detail and concluded that while each of these arguments may have validity under various assumptions or for various specific situations, the weight of currently available scientific evidence strongly supports the continued use of a linear nonthreshold model for standards-setting. EPA agrees that this conclusion is the prudent one for use in deriving radiation standards to protect public health (19). It is also recognized that rather large uncertainties remain for describing the actual situation, an uncertainty which is presently beyond scientific resolution.

The health assessments made for deriving these standards depart in two significant respects from practice common in the past for assessing the significance of radiation exposures. The first of these is the use of the concept of environmental dose commitment described earlier to assess the impact of environmental releases. Previous assessments have usually been limited to the calculation of radiation doses to individuals in local populations incurred immediately following the release of an effluent. For short-lived radionuclides this will usually suffice, but when long-lived materials are involved this practice can lead to large underestimates of the total potential impact of an environmental release. The underlying assumption justifying such a practice has been that individual doses to other than local populations and at times after the "first pass" of an effluent are so small as to be indistinguishable from those due to natural background radiation and are therefore ignorable. This point of view is not considered acceptable because it not only neglects the implications of the nonthreshold linear hypothesis for radiation effects, but also the point that the radiation doses involved are avoidable man-made doses, not doses due to natural radioactivity.

The second departure from practice usual in the past has been the use of explicit estimates of potential health effects rather than radiation dose as the endpoint to be minimized. In carrying out these assessments the results of the exhaustive review and analysis of available scientific observations on the relationship between radiation dose at low levels and health effects completed recently for the Agency by the BEIR Committee were extremely useful. It is perhaps obvious, in retrospect, that the proper focus for determination of the appropriate level for a standard should be its estimated impact on public health, but in the past minimization of dose has served as a useful surrogate for this impact because of uncertainties about the functional form and magnitude of the relationship between dose and effect. Assessments similar to those made for this statement have also appeared in some recent environmental statements for generic programs, such as those for the proposed liquid-metal fast breeder reactor program (4) and for plutonium recycle in light-water-cooled reactors (5).

The health impact analysis thus considers the total impact of releases of radioactive materials to the environment by including radiation doses committed to local, regional, national, and worldwide populations, as well as doses committed due to the long-term persistence of some of these materials in the environment following their release. The analysis served to identify which processes and effluents from the fuel cycle represent the major components of risk to populations, and leads to a clearer view of the need to control long-lived materials, as well as of the futility of excessive control measures for very short-lived radioactive materials.

In order to assist the determination of the degree of effluent control that can reasonably be required by standards, an analysis of the cost-effectiveness of risk reduction was carried out. The consideration of the cost-effectiveness of all (or, in some instances, a representative sampling) of the alternative procedures available for risk reduction within the fuel cycle reveals where and at what level effluent controls can achieve the most return for the effort and expense involved. Such an assessment of the costs and efficiencies of various forms and levels of effluent control requires that judgments be made of the availability, efficiency, and dependability of a wide variety of technological systems, and that for each of these capital and operating costs be determined over the expected life of the system. These cost data were reduced to present worth values for use in the consideration of cost-effectiveness.

Finally, although the primary consideration involved in developing these standards was reduction of the total potential health impact of radioactive effluents on large populations, doses to individuals must also be examined, since even though the total potential health impact may be at an acceptable level, extreme maldistribution of that impact may result in a few individuals receiving unreasonably high doses. A few such situations exist, for example, radioiodines from reactors and particulates from mills, where inequitably high dose levels may occur even after cost-effective control of total population impact has been achieved. Although the absolute risk to any given individual is quite small for these doses, which are generally below a few hundred millirems, EPA believes that such doses should also be minimized, especially when the individual at risk is not the direct recipient of the benefits of the activity producing them. In these cases, the approach to setting standards for maximum individual dose was to weigh the cost-effectiveness of individual dose reduction and the cost of control relative to total capital cost, in order to arrive at a judgment whether or not it was possible, at reasonable cost, to reduce these few individual exposures to the same general levels that are achievable for large populations for other sources of environmental radiation exposure from the uranium fuel cycle.

Within the context of the methodology outlined above, radioactive effluents to the environment from the nuclear power industry can be considered from three points of view:

1. the potential public health impact attributable to each effluent stream of radioactive materials from each type of facility in the fuel cycle;
2. the combined potential public health impact of the various components of the fuel cycle required to support the production of a given quantity of electrical power; and
3. the integrated potential public health impact of the entire fuel cycle due to the projected future growth of the industry over some period of time, such as through the year 2000.

The first of these is useful for assessing the effectiveness of the control of particular effluent streams from specific types of facilities. It provides the basic data from which judgments concerning the latter two perspectives flow. The second viewpoint, which provides an assessment of the total impact of the industry for each unit of the beneficial end-product (electrical power) as a function of the level of effluent control, provides the information required for assessing the potential public health impact of standards for the fuel cycle taken as a whole. Finally, although each of these perspectives assists in forming judgments as to the appropriate level of control and the public health impact associated with a unit of output from the fuel cycle, only the third provides an assessment of the potential public health impact of the entire industry. The magnitude of this future impact, which could be either considerable or relatively small, depending upon the size of this industry as well as the level of effluent control implied by the proposed standards, provides an important part of the basis for EPA's conclusion that environmental standards defining acceptable limits on the radiological impact of the industry are clearly required.

The standards-setting method described in the preceding paragraphs may perhaps be best characterized as a process of cost-effective health risk minimization which is here applied to the broad class of related activities constituting the uranium fuel cycle. This method offers, it is believed, the most rational approach to choosing standards to limit the impact of nonthreshold pollutants from an industry encompassing a wide variety of operations which combine to produce a single output.

There are, of course, a variety of alternatives to this approach to setting environmental radiation standards. These encompass the use of health considerations alone instead of considering both health risk and costs, selective instead of comprehensive coverage of the industry, use of best available technology, and, finally, the option of substituting the use of EPA influence on NRC regulatory practice for the setting of standards. Each of these alternative approaches were considered by the Agency and are discussed in Chapter VII along with some quantitative alternatives to the proposed standards that also consider both health risk and control costs.

V. TECHNICAL CONSIDERATIONS FOR THE PROPOSED STANDARDS

The sequence of operations occurring before and after the fissioning of fuel at the power reactor is shown schematically in Figure 1. Natural uranium ore (which usually contains approximately 0.2 percent natural uranium) is first mined and then milled to produce a concentrate called "yellowcake" containing about 85 percent uranium oxide. A conversion step then purifies and converts this uranium oxide to uranium hexafloride, the chemical form in which uranium is supplied to enrichment plants. At the enrichment plant the isotopic concentration of uranium-235 is increased from its natural abundance of about 0.7 percent uranium to the design specification of the power reactor (usually 2 to 4 percent) by a differential gaseous diffusion process. The greatest portion of the feed uranium hexaflouride becomes a plant tail depleted in uranium-235 content and is stored in gas cylinders. At the fuel fabrication plant the enriched uranium hexaflouride is converted into uranium oxide pellets, which are then loaded into thin zircalloy or stainless-steel tubing and finally fabricated into individual fuel element bundles. These bundles are used to fuel the reactor. After burnup in the reactor, the spent fuel is mechanically sheared and chemically processed in order to remove

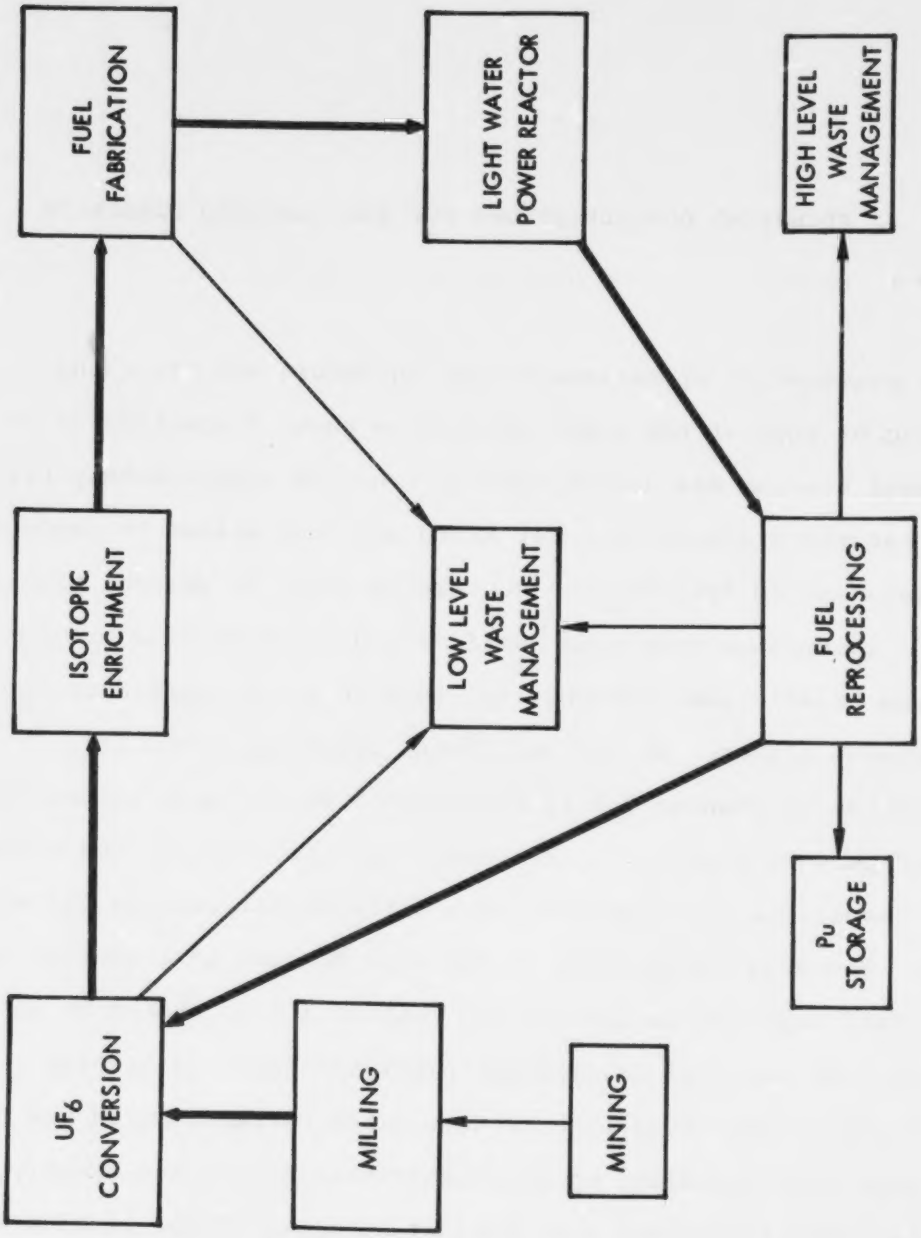

Figure 1. URANIUM FUEL CYCLE FACILITY RELATIONSHIPS

radioactive waste products and to reclaim fissile material (mainly plutonium and unused uranium) for reuse. Each of these operations depend upon the transportation of a variety of radioactive materials.

Table 1 shows basic parameters that are representative of typical facilities for each of these fuel cycle operations (20). The values which relate these operations to the number of gigawatts of power production supported can be used as the basis for an assessment of the environmental impact of the fuel cycle as a whole. A projection of the magnitude of fuel cycle operations required to support reactors through the year 2000 is shown in Figure 2 (7). Currently existing capacity is expected to be sufficient to accommodate the requirements of the fuel cycle up to about the year 1980, with the exception of fuel reprocessing operations. In this case, a single facility is expected to become operational within a few years, with additional capacity becoming operational in the 1980's.

The environmental impacts due to radioactive materials associated with the various operations comprising the uranium fuel cycle fall into four major categories. These are: 1) doses to populations and to individuals due to naturally-occurring radioactive materials from operations prior to fission in the reactor; 2) doses to populations and individuals from short-lived fission and activation products; 3) doses to populations from long-lived fission products and transuranic elements; and 4) gamma and neutron radiation from fuel cycle sites and radioactive waste products and to reclaim fissile material (mainly plutonium and unused uranium) for reuse. Each of these operations depend upon the transportation of a variety of radioactive materials.

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TABLE 1

CHARACTERISTICS OF MODEL FUEL CYCLE FACILITIES

Operation[1]	Fuel Cycle Plant Annual Capacity		Number of Model LWR's Supported by Facility
	Range	Model	
Uranium Mill (MT U_3O_8)	500-1100*	1140	5.3
UF_6 Production (MT U)	5000-10,000	5000	28
Isotopic Enrichment (swu)	6000-17,000	10,500**	90
UO_2 Fuel Fabrication (MT U)	300-1000	900	26
Light-Water-Cooled Reactor (GW(e) capacity)	0.04-1.3	1	1
Spent Fuel Reprocessing (MT U)	400-2100	1500	43

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[1] The units which characterize each type of operation are abbreviated as follows: Metric Tons = MT; separative work units = swu; and gigawatts(electric) = GW(e).

*Characteristic of about 70% of current facilities.

**Current operating level of industry and assumed model plant capacity.

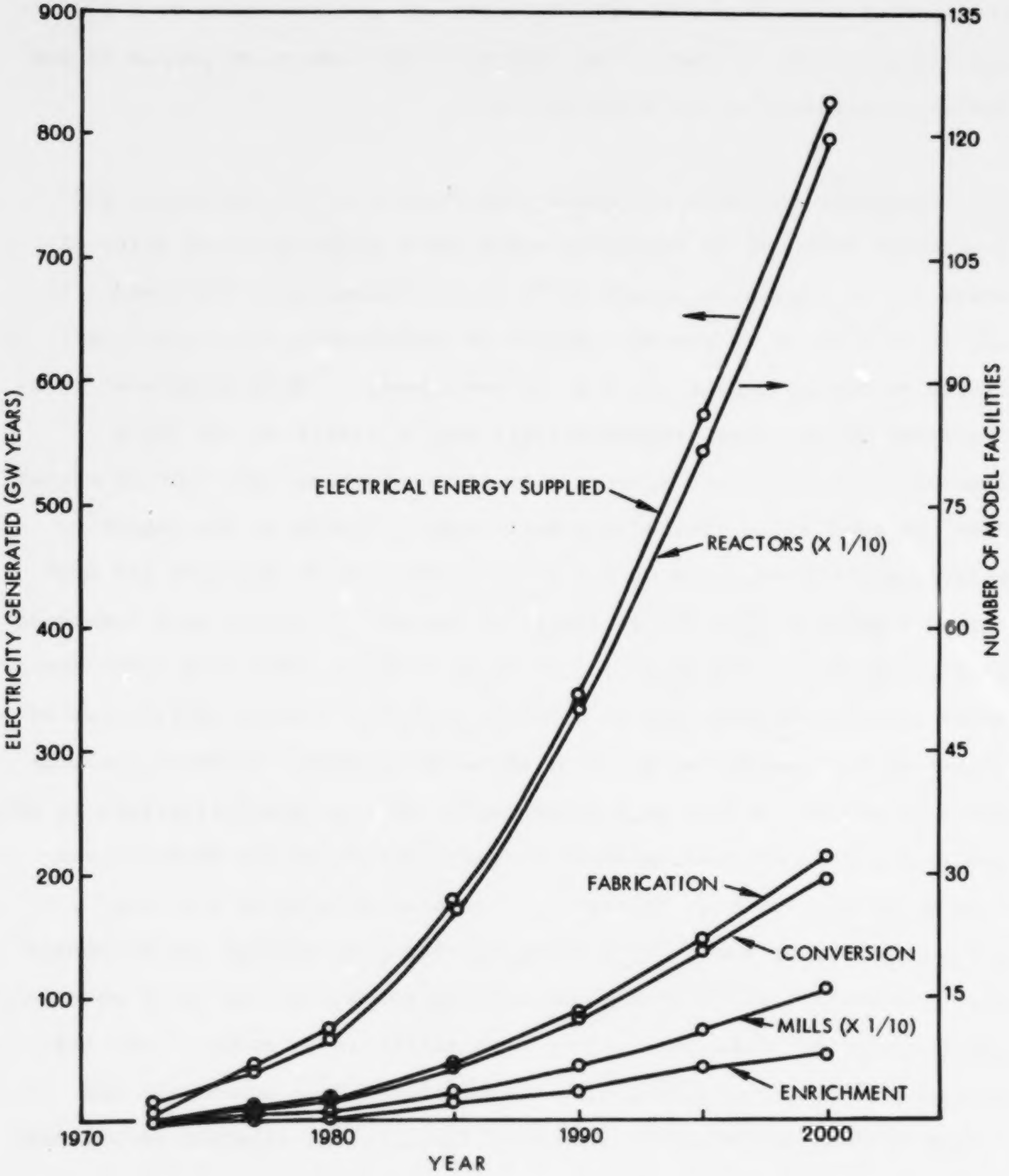


Figure 2. PROJECTED NUCLEAR FUEL CYCLE FACILITY NEEDS

transported radioactive materials, which may produce doses to a few individuals close to facilities, and to large numbers of people at low levels of exposure along shipping routes.

Standards to limit the above four categories of individual and population dose can be expressed using three major kinds of units of measure: 1) limits on annual doses or individual dose commitments to the whole body or to specific organs of individuals (millirems/year); 2) limits on annual population dose or environmental dose commitment (man-rems/year or man-rems, respectively); and 3) limits on the total discharge of long-lived materials to the environment per unit of output from the fuel cycle (curies/gigawatt-year). Limits on the impact on individuals through each of the above categories of exposure are most easily expressed directly as limits on annual individual dose commitment (millirems/year). Control of population impacts, both from long- and short-lived materials, can be achieved directly through application of either of the latter two kinds of units of measure. However, although the best measure of the population impact of long-lived materials is the environmental dose commitment (man-rems), standards expressed in man-rems would be extremely difficult to enforce because of the many pathways and wide choice of models for transport through the biosphere that are available. A more reasonable approach for long-lived materials is to limit the total quantity of such materials introduced into the environment by first calculating environmental dose commitment and health effects and then deciding what limit on the directly measurable quantity (the quantity released to the environment measured in curies) best achieves the level of protection indicated. Furthermore, analysis of dose distributions indicates that the population impact of short-lived materials is quite adequately limited by a limit on individual exposure, and that a separate limit for the impact of these materials on populations expressed in man-rems/year is an unnecessary redundancy. Thus, standards for the fuel cycle expressed in just two kinds of units of measure (millirems/year and curies/gigawatt-year) are adequate to limit both the total population impact of fuel cycle operations and, at the same time, maximum individual risk.

Table 2 summarizes the principal types of radioactive effluents from the fuel cycle and the associated target organs which are of greatest concern. The degree of environmental protection appropriate to minimize the public health impact of these (as well as other less important effluents) may be assessed using three complementary sources of information: 1) projections based upon modeling of source terms, the capabilities of effluent control, and environmental pathways, 2) measurements of the actual performance of existing facilities, and projections based upon these measurements for improved levels of effluent control, and 3) the performance anticipated by the industry, the Atomic Energy Commission, and the Nuclear Regulatory Commission as reflected by recently filed environmental statements for a variety of fuel cycle facilities.

TABLE 2

PRINCIPAL RADIOACTIVE EFFLUENTS FROM THE URANIUM FUEL CYCLE AND THE ASSOCIATED CRITICAL ORGANS

Effluent	Principal Critical Organ(s)
Noble gases	Whole body
Radioiodine	Thyroid
Tritium	Whole body
Carbon-14	Whole body
Cesium and other metals in liquids	Whole body, G.I. tract
Plutonium and other transuranics	Lung
Uranium and daughter products	Lung, bone
Gamma and neutron radiation	Whole body

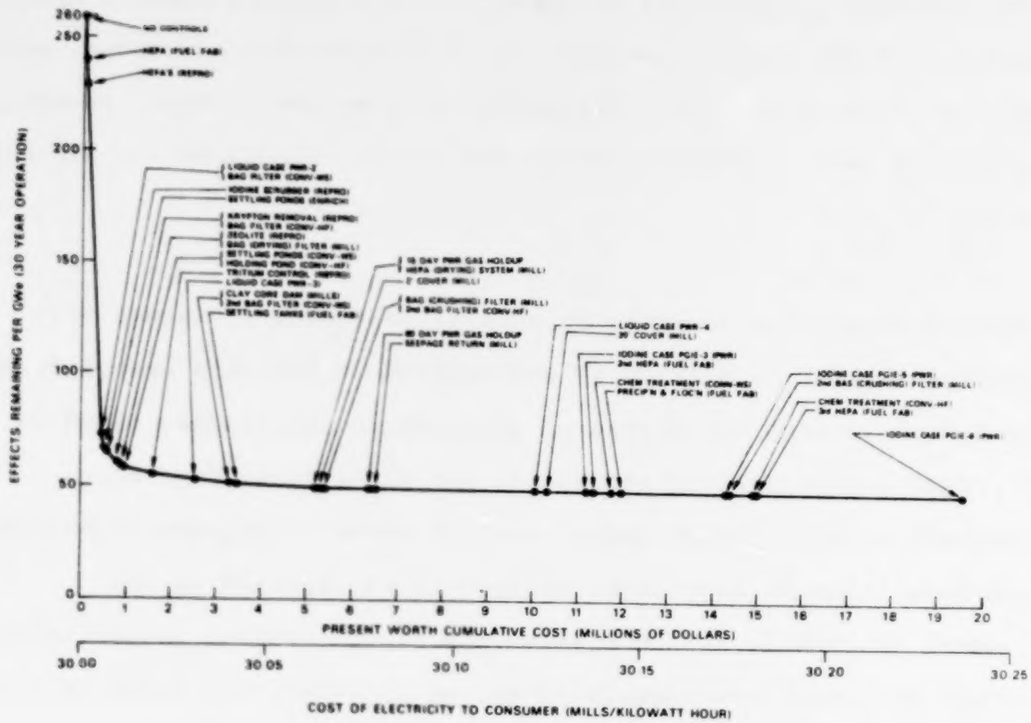
The most complete set of information available is that derived from model-based projections. For this reason, the principal inputs for judgments about acceptably low levels of environmental impact are based upon this data base. The rationale for these judgments is described in Section A below, which also summarizes the results of these projections. Sections B and C present data from environmental statements and field measurements for specific facilities, respectively. These data in some instances confirm the conclusions drawn from models, and in others point out areas where modifying judgments are appropriate. The final section describes the conclusions reached by the Agency for the proposed standards.

A. MODEL PROJECTIONS OF FUEL CYCLE ENVIRONMENTAL IMPACTS

There are several elements to the development of a projection of the potential health impact of radioactive effluents. The first is a determination of effluent source terms as a function of the level of effluent control. Next, the assumed radionuclide effluents must be followed using semiempirical models over as wide an area and for as long a period as they may expose human populations. Human doses are then calculated from the radionuclide concentrations projected by these models for air, water, and foodstuffs. For each radionuclide this involves modeling of the penetration of the radiation through body tissues, rates of ingestion and excretion, and partition among and metabolism in the various organs of the body. Finally, after doses to various critical organs have been determined, the probabilities of incurring somatic and genetic health effects attributable to these doses are estimated.

These projections have been carried out and are described in detail for each of the major effluent streams from the various activities comprising the fuel cycle in the EPA reports entitled "Environmental Analysis of the Uranium Fuel Cycle" (7,8,9,10). The results of these analyses include both the reduction in potential health impact and the costs of a large variety of measures that can be instituted within the fuel cycle to reduce its environmental impact. These have been summarized in Figures 3a and 3b for the entire fuel cycle by using the normalizing factors shown in Table 1 for the typical model facilities described in detail in references 7-10. Figure 3a displays the reduction in potential health effects achieved as a function of cumulative incremental control system costs to the entire fuel cycle for the case of a typical pressurized water reactor, for a representative variety of control options on each component of the cycle. The costs of control have been normalized to one gigawatt of electric power output and were applied in the order of decreasing cost-effectiveness of health effects reduction for the fuel cycle, taken as a whole. A similar curve can be constructed for the fuel cycle for the case of a typical boiling water reactor, and is shown in Figure 3b. It should be noted that many, if not most, of the types of controls shown are representative of

(PWR CASE)



(BWR CASE)

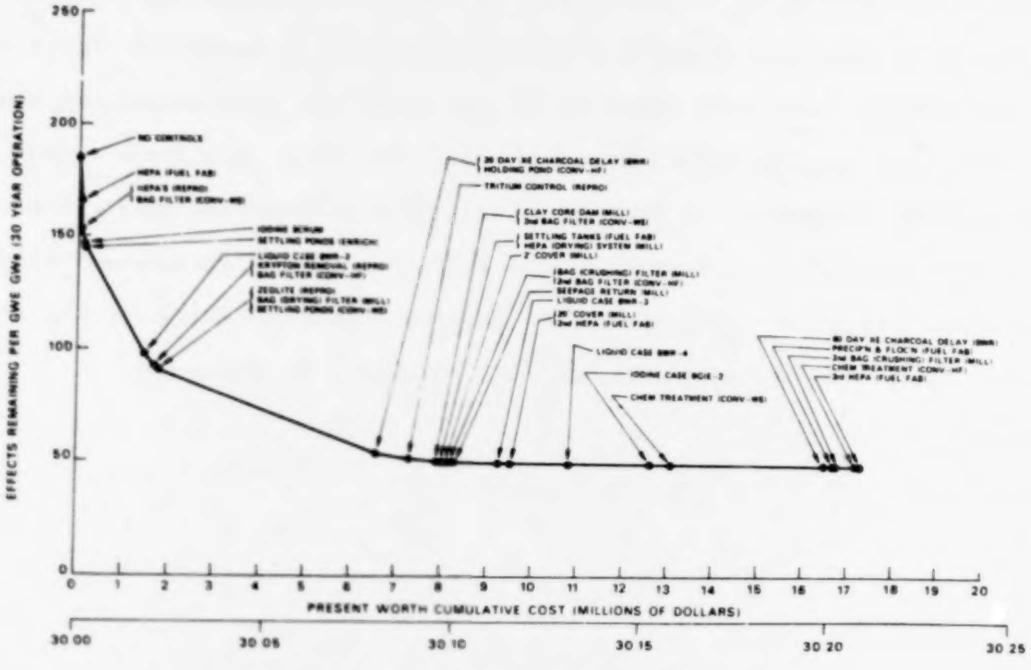


FIGURE 3. RISK REDUCTION VS. COST FOR THE URANIUM FUEL CYCLE

current practice. A detailed discussion of the various control options displayed on these figures, as well as of alternatives not shown, will be found in references 7-10. The examples shown are typical, however, and provide a good representation of the options available for effluent reduction.

The rationale for deriving an acceptable choice of values for standards described in Section IV was applied to the data exemplified by Figure 3 to determine the levels of performance achievable, based on model projections. Table 3 shows, for the major categories of radiological impact, the projected maximum doses to exposed individuals and the quantities of long-lived radionuclides released to the environment achievable at the levels of effluent control judged to be consistent with such considerations as: a) an acceptable level of cost-effectiveness of risk reduction, b) an equitable distribution of radiological impact, or c) the existing use of technology by industry as the result of non-radiological considerations. The numerical criteria used for judging the acceptability of the level of cost-effectiveness of risk reduction are discussed later in this section. The second and third columns indicate the type of facility at which each major impact occurs and the level of control which has been judged environmentally acceptable, respectively. The final column indicates which of the above considerations was controlling for each category of exposure.

TABLE 3

DOSE AND QUANTITY LEVELS IMPLIED BY PROJECTIONS

	Level[†]	Source	Control[††]	Limiting Factor
A. Maximum Annual Individual Doses (mrem/yr)				
1. Whole Body				
a. Noble Gases	<1	PWR	1B-15	C/E
	1-5	BWR	2-20	C/E
	<1	FR	Note 1	C/E
b. Tritium	3	FR	None	Not Available
c. Carbon-14	<1	FR	Note 1	C/E
d. Cesium, etc.	<1	PWR	PWR-3	C/E
	<1	BWR	BWR-3	C/E
	3	FR	Note 2	C/E
2. Lung				
a. Plutonium, etc.	1	FR	HEPA	C/E
b. Uranium, etc.	11	Mill	Filter	C/E
	10	Fab	HEPA	Recovery of Uranium
3. Thyroid-Radioiodine[*]	2-9	PWR	PGIE-3,0-5	Maximum Individual
	1-8	BWR	BGIE-2,0-5	Maximum Individual
	15	FR	Note 3	C/E
4. Bone - Uranium, etc.	13	Mill	Clay Core	C/E
B. Maximum Quantities Released to the Environment, Per Gigawatt-Year of Electric Power (Curies)				
1. Tritium	30,000	FR	None	Not Available
2. Carbon-14	~20	LWR	Note 1	C/E
3. Krypton-85	4000	FR	Note 1	C/E
4. Iodine-129	<0.002	FR	Note 3	C/E
5. Plutonium, etc.[**]	<0.0003	FR	HEPA	C/E

[†] All doses are rounded to the nearest number of millirems/year at the location of maximum dose outside the facility boundary.

[††] System designations are those used in Ref. 48; the levels at LWR's are for 2 units.

[*] At the nearest farm in the case of elemental release of iodine, and at the nearest residence in the case of organic releases; dose ranges shown encompass that for 100% release of either form.

[**] Defined as alpha-emitting transuranics of half-life greater than 1 year.

Note 1 Assumes krypton retention via any of several alternative methods of equivalent cost. Such control is assumed to permit the retention of the approximately 60% of carbon-14 produced by the fuel cycle that is released by fuel reprocessing at negligible additional cost. The balance shown is released at the reactor.

Note 2 In addition to tritium whole body exposures at fuel reprocessing, cesium-137, ruthenium-106, and iodine-129 may combine to yield comparable whole body doses. The dose shown is that remaining in the presence of cost-effective levels for control of other major effluents (particularly transuranics and iodine).

Note 3 Assumes iodine control is available with a removal efficiency of 99.9% for both iodine-131 and iodine-129. Although some uncertainty exists concerning the performance of immediately available systems, systems presently under active development should achieve such efficiencies and become available prior to expansion of the fuel reprocessing industry to more than one or two facilities following the year 1980.

The results shown in Table 3 indicate that at these levels of control of environmental releases the attainable range of maximum annual whole body dose to an individual at the boundaries of representative reactor sites (for the unlikely case of simultaneous exposure to air and water pathways) is 0-2 mrem/yr for pressurized water reactors and 1-6 mrem/yr for boiling water reactors. All of the three major types of sites (river, lake, and seacoast) are included in the projections which yielded these dose ranges. At a few atypical boiling water reactors on small sites, gamma radiation doses from skyshine due to nitrogen-16 in turbine building components may be significant compared to these values. However, in such cases, additional concrete shielding will reduce these doses to a few mrem/yr (10). A large (1500 metric tons per year) fuel reprocessing facility is expected to exhibit maximum doses of 6-8 mrem/yr to the whole body. The only other source of exposure in the fuel cycle which has the potential to produce whole body doses of significance in comparison to these types of facilities is tailings at milling operations, which may produce gamma doses to the whole body if not properly stabilized against wind and aqueous erosion. However, if these tailings are stabilized to the degree required to adequately control lung doses, the residual gamma doses to the whole body are small.

It should be noted that the cases considered in this analysis assume two one gigawatt(electric) power reactors on each site. Larger numbers of reactors would require larger sites in order to achieve these doses at the boundary, or, alternatively, a greater degree of effluent control. It is anticipated, based on experience, as well as environmental and other considerations not related to radioactive effluents, that sites used for multiple reactor installations will, in practice, be significantly larger than those for single or twin reactor installations, and that in those instances where this is not the case the economies associated with the use of smaller sites and multiple installation of reactors will readily accommodate the slightly higher costs of improved effluent control required to maintain the above dose levels. An additional factor influencing the maximum doses at sites with large numbers of reactors is the small likelihood that all of the limiting fuel failure and leakage parameters assumed in order to model the effluent source terms will be realized by all of the reactors on a site simultaneously. The matter of doses anticipated from sites with more than two reactor units is elaborated upon at length in Section VI-F.

Maximum potential annual doses to the lung and to bone from the fuel cycle occur at mills and at fuel fabrication facilities. These doses result from the release of dust containing natural or enriched uranium. At fuel fabrication facilities current releases are restricted to levels corresponding to maximum lung doses of approximately 5 mrem/yr, due to the incentive provided by the recovery of valuable enriched uranium. Readily achieved levels of effluent control at mills and other facilities associated with the supply of uranium fuel to reactors lead to comparable or lower doses to the lung, as well as to bone. In the case of some mills achievement of this level will involve use of dust control measures at tailings piles, as well as additional effluent controls on mill operations themselves. For a detailed discussion of effluent controls at mills see reference 10, "Supplementary Analysis - 1976."

Thyroid doses due to environmental releases of short-lived radioiodines from the fuel cycle are particularly difficult to model realistically due to uncertainties in the magnitudes and effective release heights of source terms and the chemical form in which iodine is released, as well as complicated environmental pathways, which, in addition to direct inhalation, typically involve airborne transport of iodine to vegetation (the extent of which is extremely sensitive to rainfall), immediate or delayed uptake by cows, and, following an indefinite additional period of delay, final ingestion by humans in milk. Doses calculated from milk ingestion are subject to uncertainties due to dilution resulting from milk pooling in addition to those resulting from the relatively rapid decay of radioiodine (half-life of iodine-131 = 8.1 days). Because of all of these uncertainties, model calculations of thyroid dose are generally anticipated to be markedly more conservative than those for most other effluents - i.e., actual doses are expected to be considerably lower than calculated doses. The model calculations project maximum individual thyroid doses of 1-9 mrem/yr from typical reactor sites at the locations of either permanent residents or at nearest farms.

The radioiodine situation at fuel reprocessing plants is even more uncertain than that at reactors, because of a lack of experience with many of the control methods for iodine appropriate to these plants and the paucity of knowledge concerning the chemical form of radioiodine effluents. In addition to the variety of control methods currently available, a number of more advanced methods are now in final stages of development. Currently available systems provide cost-effective control of iodine emissions with anticipated effluent stream decontamination factors of 100 (10). Since no fuel reprocessing facility is expected to become operational before 1980, and only one or two more during the following decade, it is important to also consider more advanced systems that are expected to become available during that time period. These include iodine evolution at the dissolution stage of reprocessing, and the iodox process (10,21). These systems should permit the achievement of decontamination factors approaching 1000, and are not anticipated to represent a major increase in the cost of fuel reprocessing. Development programs for these systems have been underway for a number of years at Oak Ridge National Laboratory, and most are in final stages of pilot scale demonstration, having completed laboratory scale testing. A further consideration is that it is highly unlikely (and unnecessary) that fuel will be processed at 150 days after removal from the reactor, as previously proposed. For a number of years in the foreseeable future most reprocessed fuel will be more than a year old and therefore have negligible content of short-lived radioiodines. It thus appears reasonable to assume that within the next few years overall plant decontamination factors of at least 300 can be readily achieved. On this basis, the calculated maximum thyroid dose from a fuel reprocessing facility would not exceed 15 mrem/yr.

The second part of Table 3 reflects the capabilities of cost-effective control techniques for long-lived radionuclides, where they are available. It should be noted that although tritium control is not yet available, the voloxidation process now under active development for fuel reprocessing for the LMFBR program would make possible effective control of the largest source of tritium from the uranium fuel cycle. This development program is not expected to be completed for more than a decade, however (22), and its cost is anticipated to be high.

Carbon-14 has only recently been recognized as a fuel cycle effluent of potentially large impact (23), and control methods have not yet been extensively investigated. However, retention of krypton-85 by either cryogenic distillation on selective absorption at fuel reprocessing (two of the principle control options for this radionuclide) would permit, at small additional cost, the simultaneous removal of carbon-14 as carbon dioxide.

Specific control options for krypton-85, iodine-129, and plutonium and other long-lived transuranics are discussed in references 9 and 10. In addition, a detailed review of krypton-85 control is presented in Section VIII-B of this Statement. The comments above concerning control systems for retention of short-lived iodine-131 at fuel reprocessing also apply to iodine-129. Controls for plutonium and other transuranics are well established technology; those for krypton-85 and iodine-129 are either developed and currently becoming available for commercial use or demonstrated in the laboratory and in the final stages of development for commercial use.

We return now to a discussion of the choice of criteria for acceptable levels of risk reduction. The display of the options available for reducing the environmental impact of the fuel cycle shown in Figure 3 can be examined from several points of view. If a certain number of health effects were presumed justified in order to obtain the generation of a given quantity of electricity, then this curve would allow a judgment to be made as to which controls should be used in order to meet that criterion at the lowest cost. If, on the other hand, a determination had been made that the total cost of control should not exceed a fixed amount, the curve can be used to make a determination of the maximum amount of health effects reduction possible. However, such judgments are not available for either of these simple constraints with regard to the generation of electricity. A judgment of the appropriate level of environmental control must instead consider a variety of issues. These include such matters as: a) the limiting rate up to which society is willing to incur costs to prevent deleterious effects on health, b) the availability of improved control technology not yet in use, as well as present patterns of use of control technology, installed for the reduction of radioactive effluents, in order to recover valuable materials, or for other reasons, and c) the distribution of potential health effects, i.e., should a few individuals incur relatively larger risks so that others may receive the benefit of an industry's operation.

If the data in the cost versus health effect curves in Figure 3 are plotted as differential curves, as shown in Figure 4, a display of the rate of aversion of health effects per unit cost versus cumulative cost is obtained. An examination of these curves in conjunction with Figure 3 shows that near a cumulative present worth cost of about three million dollars per gigawatt of power capacity for the entire fuel cycle for the PWR case (about eight million dollars for the BWR case), a breakpoint occurs between efficient and inefficient control options. At this point the rate of reducing potential health effects is roughly one per half-million dollars. In the region beyond this point, the differential curve continues to descend rapidly to very low rates of cost-effectiveness (note that the vertical scale is logarithmic, not linear), and an insignificant further reduction in health effects is obtainable even for large additional control expenditures.

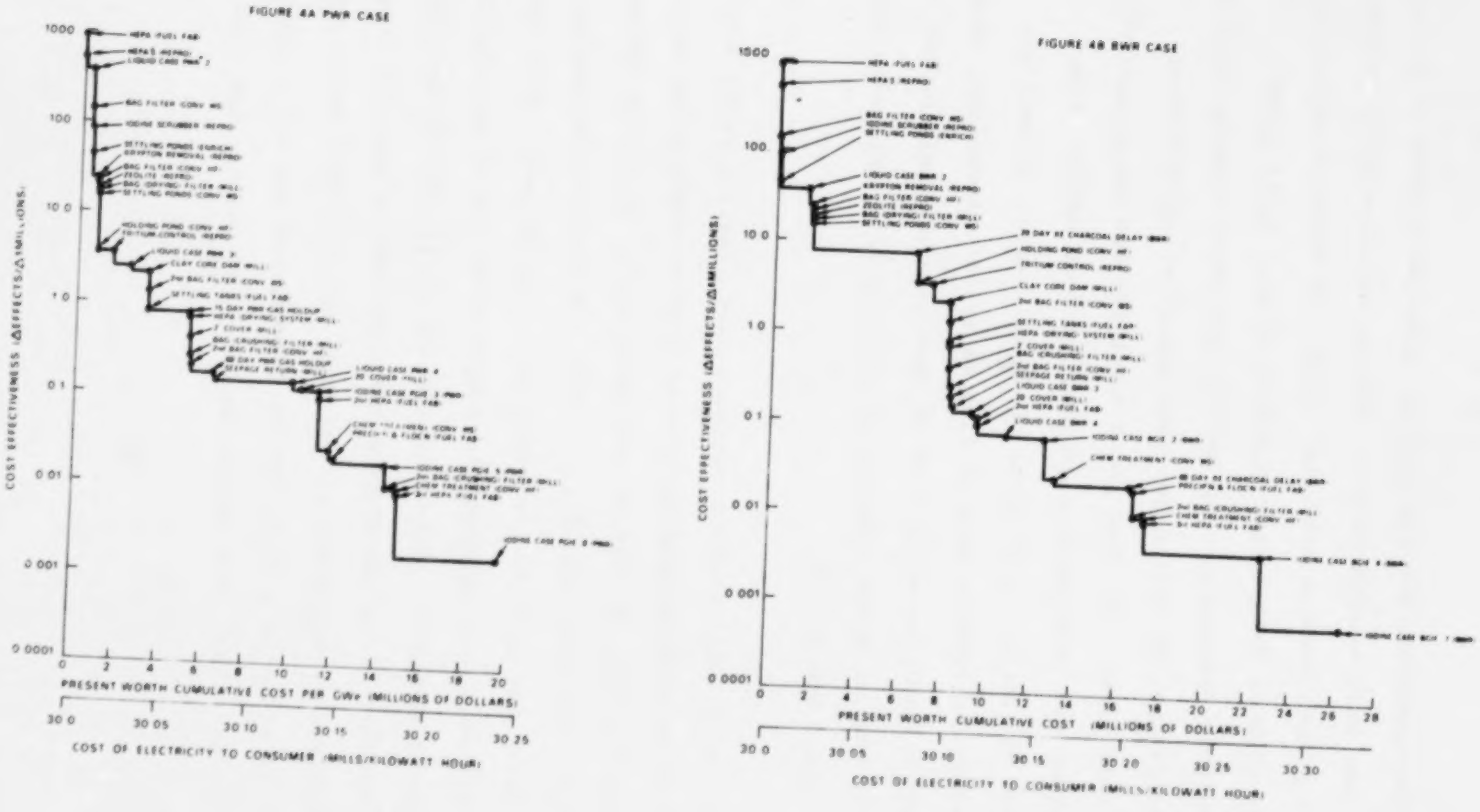


FIGURE 4A PWR CASE

FIGURE 4B BWR CASE

FIGURE 4. COST EFFECTIVENESS OF RISK REDUCTION FOR THE URANIUM FUEL CYCLE

If the sole criterion for choosing an acceptable level of potential health impact was that expenditures to achieve health effects reduction stop at such a point, then no more cost should be incurred beyond about three or eight million dollars per gigawatt of fuel cycle power generating capacity (depending upon whether the power reactor is a PWR or BWR, respectively), no matter how many potential effects were remaining at that level. At this point resources are being committed at the rate of about one half million dollars for each health effect averted. Since the majority of these potential health effects are serious in nature, involving loss of life or severe disability, this could be taken as implying acceptance of that rate as limiting for preventing the loss of human life due to the impact of effluents from uranium fuel cycle operations.

It is extremely difficult to estimate what limiting value society actually places on expenditures to prevent loss of human life, because so many intangible factors must be evaluated (24). This task becomes especially difficult when one is faced with the question of preventing the loss of life; the task is less difficult, but no more exact, when considering the choice of appropriate compensation for a specific loss that has already occurred. Leaving aside the moral implications of assigning a monetary value to compensation for such a specific loss, and considering only the experience we can draw upon for what society has been willing to spend to prevent future losses, one can distinguish several characteristics. The amount depends upon whether the risk of incurring the effect is imposed voluntarily or involuntarily (the latter case carrying a much greater willingness to spend) and how far into the future it is anticipated to occur. The amount also depends upon who is supplying it and upon how the burden of payment is distributed. In addition, the historical trend is for steadily increasing amounts.

Most current estimates of the acceptable limiting rate of investment for the prevention of future loss of life appear to fall at or below an upper limit of one-quarter to one-half million dollars (25), just below the value, noted above, at which the cost-effectiveness of health effects reduction for the fuel cycle reaches a point of rapidly diminishing return. This range of estimates of the acceptable limiting value for prevention of future loss of life corresponds to a minimum cost-effectiveness of risk reduction of two to four effects per million dollars. Returning to the curves in Figure 4 displaying cost-effectiveness of risk reduction, it can be seen that most of the systems which lie above or within this range of cost-effectiveness (with the important exceptions of krypton and tritium control) have already been developed and are either available for immediate application or are already being applied by the industry in response to a variety of factors that are not as well defined, perhaps, as the explicit health effect and cost considerations developed here, but are present nonetheless. It seems reasonable, therefore, that levels of environmental protection achievable by systems of cost-effectiveness greater than this range of values should be required, and that levels of protection that can only be achieved using systems of lower cost-effectiveness should not be required unless other extenuating circumstances exist. Such circumstances may be that they are currently already included in facility designs for a purpose not related to radiation control, or that their use may be indicated in some instances to bring about the reduction of excessive doses to specific individuals in the general environment, that is, to ameliorate extreme maldistribution of impact within the population. The levels of control shown above in Table 3 were chosen to satisfy these criteria.

B. RESULTS FROM ENVIRONMENTAL ASSESSMENTS UNDER NEPA

For the past four years, an extensive program has been carried out by the utilities, manufacturers, and the AEC (and its successor, the NRC) in order to assess the expected performance characteristics of nuclear power facilities, for each of which the AEC (now the NRC) is required to file an environmental statement under the provisions of the National Environmental Policy Act of 1969 (26). By the end of 1974, environmental statements had been submitted for 152 reactors at 82 different sites. These analyses provide unusually detailed descriptions of the impact of facilities at specific sites. For each site such details as the local meteorology, topography, population distribution, water usage patterns, and land usage patterns (including the locations of nearby permanent residences, vegetable and dairy farms, and recreational facilities) are considered with respect to each pollutant released to the environment. The sample of statements available encompasses every important power consuming region of the United States and every significant geographical situation. Individually and collectively, these assessments represent the most comprehensive analysis ever performed of the potential impact of an industry upon the environment.

Tables 4, 5, and 6 summarize the results of these analyses for radioactive releases from pressurized water reactors, boiling water reactors, and other fuel cycle facilities, respectively. The results for reactors are listed in order of the most recently filed environmental statement for each site. In cases where more than one statement has been filed the most recent has been used. The statements are all final unless otherwise indicated. For each reactor site the maximum whole body doses due to gaseous releases, liquid releases, and gamma radiation from the site, as well as the maximum thyroid dose to a child's thyroid (calculated at the nearest pasture) are shown. In the case of other fuel cycle facilities, the maximum whole body, thyroid, lung, and/or bone doses are shown, as is appropriate for the particular type of facility considered.

Table 4 demonstrates that for over 90 percent of the 52 sites containing PWR's, maximum whole body doses from gaseous releases no greater than 1 mrem/yr are anticipated. For three, maximum doses of 2

TABLE 4. Environmental Impacts of Pressurized Water Reactors

Facility (No. of Units)	EIS (Date)	Exposure Mode			
		Gaseous	Liquid	Site Gamma*	Iodine (Thyroid)
		(Whole-body)			
Byron (1)	7/74	<1	2	<1	9
Pilgrim (3)[a]	6/74 (draft)	1	<1	<1	4
Commanche Peak (2)	6/74	<1	1	<1	5
Bellefonte (2)	6/74	<1	<1	<1	<1
Fulton (2)[f]	5/74 (draft)	1	<1	<1	<1
St. Lucie (2)	5/74	<1	<1	<1	4
Surry 3 & 4 (2)	5/74	<1	<1	<1	1
Braidwood (2)	4/74 (draft)	1	1	<1	3
Seabrook (2)	4/74 (draft)	<1	<1	<1	12
Vogtle (4)	3/74	<1	<1	<1	4
S. Harris (4)	3/74	<1	12[b]	<1	15[c]
Millstone (3)[a]	2/74	<1	<1	<1	10
Sequoyah (2)	2/74	2	<1	<1	<1
R. E. Ginna (1)	12/73 (draft)	<1	<1	<1	<1
Catawba (2)	12/73	<1	1	<1	15
Indian Point (3)	10/73 (draft)	2	<1	<1	6
Haddam Neck (1)	10/73	<1	2	<1	5
Trojan (1)	8/73	<1	<1	N.R.	<1
D. C. Cook (2)	8/73	<1	<1	<1	3
Beaver Valley (2)	7/73	<1	<1	N.R.	2
Diablo Canyon (2)	5/73	<1	<1	N.R.	<1
Crystal River (1)	5/73	<1	<1	<1	2
Prairie Island (2)	5/73	<1	<1	N.R.	2
H. B. Robinson (1)	4/73 (draft,	<1	2	<1	2
North Anna (4)	4/73	<1	1	<1	<1
Calvert Cliffs (2)	4/73	<1	<1	<1	3
Salem (2)	4/73	<1	<1	<1	4
Waterford (1)	3/73	<1	4	N.R.	5
San Onofre (3)	3/73	<1	<1	<1	<1
Davis-Besse (1)	3/73	<1	3	<1	1

TABLE 4. Environmental Impacts of Pressurized Water Reactors (cont.)

Facility (No. of Units)	EIS (Date)	Exposure Mode			
		Gaseous	Liquid (Whole-body)	Site Gamma*	Iodine (Thyroid)
Rancho Seco (1)	3/73	<1	3	N.R.	1
Arkansas (2)	2/73	<1	<1	N.R.	4
Forked River (1)	2/73	<1	1	<1	<1
V. Summer (1)	1/73	<1	5b)	N.R.	8
Three Mile Island (2)	12/72	<1	<1	<1	5d)
Zion (2)	12/72	1	<1	N.R.	3
Kewannee (1)	12/72	<1	1	N.R.	4
Watts Bar (2)	11/72	2	<1	<1	3
McGuire (2)	10/72	<1	<1	<1	<10
Fort Calhoun (1)	8/72	<1	<1	N.R.	10
Maine Yankee (1)	7/72	<1	<1	N.R.	<1
Turkey Point (2)	7/72	<1	<1	<1	<1
Surry 1 & 2 (2)	6/72	<1	<1	<1	48e)
Farley (2)	6/72	1	<1	N.R.	12
Palisades (1)	6/72	<1	3	N.R.	1
Point Beach (2)	5/72	1	<1	N.R.	5
Midland (2)	3/72	4	<1	N.R.	<1
Oconee (3)	3/72	1	<1	N.R.	5

N.R. = Not Reported.

*500 hours unshielded occupancy of boundary per year.

a) One BWR and two PWR units.

b) Assumes public access to cooling water discharge canal and consumption of 18 kg of fish and mollusks raised in discharge per year.

c) Monitoring and appropriate operational practices will be required by the AEC to maintain this dose level, however, the AEC considers the dose calculated without use of such measures (28 mrem/yr) very conservative (i.e., the actual dose will be lower).

d) The dose calculated in the EIS (18.5 mrem/yr) will be reduced to this level by changes in control capability required of the applicant by the AEC.

e) 98% of the release is from the condenser air ejector and steam generator blowdown, and can be eliminated through simple modifications of existing control equipment.

f) Two HTGR units.

TABLE 5. Environmental Impacts of Boiling Water Reactors

Facility (No. of Units)	EIS (Date)	Exposure Mode			
		Gaseous	Liquid	Site Gamma*	Iodine (Thyroid)
		(Whole-body)			
River Bend (2)	9/74	<1	<1	<1	22[a,b]
Allen's Creek (1)	7/74 (draft)	<1	<1	<1	<1
Clinton (1)	6/74 (draft)	<1	<1	<1	2
Pilgrim (3)[c]	6/74 (draft)	1	<1	<1	4
Douglas Point (2)	5/74 (draft)	<1	<1	1	6
Perry (2)	4/74	<1	<1	<1	24[a,b]
Hope Creek (2)	2/74	<1	1	3	1
Millstone (3)[c]	2/74	<1	<1	1	10
Nine Mile Point (2)[d]	1/74	<1	<1	12	<1
Brunswick (2)	1/74	<1	<1	<1	28[e]
Limerick (2)	11/73	1	<1	<5	<1
Dresden (3)	11/73	<1[f]	<1	<1	7
Grand Gulf (2)	8/73	2	4	<1	3
Oyster Creek (1)	7/73 (draft)	<1	<1	<1	6
Susquehanna (2)	6/73	4	<1	<1	<10
Peach Bottom (2)[g]	4/73	8	<1	<1	480[h]
Fitzpatrick (2)	3/73	3	<1	3	11
Duane Arnold (1)	3/73	1	<1	<1	7
LaSalle (2)	2/73	<1	<1	<1	9
Bailly (1)	2/73	1	4	25	<1
Cooper (1)[i]	2/73	5	4	N.R.	5
Hanford No. Two (1)	12/72	3	<1	<1	3
Monticello (1)	11/72	1	<1	N.R.	29[b]
Hatch (2)	10/72	1	<1	<1	17[a,b]
Zimmer (1)	9/72	<1	<1	<1	9
Shoreham (1)	9/72	2	<1	N.R.	<1
Brown's Ferry (3)	9/72	2	<1	<1	<1
Quad Cities (2)	9/72	4	<1	N.R.	2
Vermont Yankee (1)	7/72 (draft)	<1	<1	N.R.	7
Fermi Unit Two (1)	7/72	2	<1	N.R.	<28[j]

(Footnotes next page)

TABLE 5. Environmental Impacts of Boiling Water Reactors (cont.)

FOOTNOTES

N.R. = Not Reported.

*500 hours unshielded occupancy of boundary per year.

a) The AEC has required installation of additional equipment to maintain doses to less than 15 mrem/yr in its comments on the EIS.

b) At least three-fourths of the projected dose is due to turbine building exhaust, which is untreated.

c) One BWR and two PWR units.

d) Includes the contribution from Fitzpatrick. The site gamma dose assumes 100 hours in a boat at point of nearest approach per year. The figures shown are after scheduled 1975 augment of unit one gaseous effluent control.

e) The AEC also calculates a dose of 43 mrem/yr through the goat-milk pathway; more than half of the dose is due to turbine building effluent, applicant is evaluating improved systems.

f) The dose of 22 mrem/yr in Table 5.3 of the EIS for unit one will be reduced by a factor of 100 by a scheduled augment committed by the applicant (see p.11-40 of the EIS).

g) Plus one 40 MW(e) HTGR.

h) Applicant calculates a maximum dose of 0.45 mrem/yr. AEC will require applicant to reduce iodine dose to "as low as practicable" levels (see summary comments on EIS).

i) EIS lists calculated doses of up to 10 mrem/yr (whole-body) and of 95 mrem/yr (infant thyroid), but applicant has committed to install additional control equipment to insure no greater than 5 mrem/yr for both pathways.

j) Assumes a hypothetical cow grazing at the site boundary. Distance to the nearest pasture was not determined in this early EIS.

TABLE 6

ENVIRONMENTAL IMPACTS OF OTHER FUEL CYCLE FACILITIES

Facility (Type)	EIS (Date)	Exposure (mrem/yr)			
		Whole Body	Thyroid	Lung	Bone
Humeca (mill)	12/72 (draft)	--	--	11	42[1]
Highland (mill)	3/73	--	--	<1	3-12
Shirley Basin (mill)	12/74	--	--	1	<1
Sherwood (mill)	4/76 (draft)	--	--	<1	<1
Sequoyah (conversion)	5/75	--	--	3	<1
Barnwell (conversion)	4/75 (draft)	--	--	<1	1
Exxon Nuclear (fabrication)	6/74	--	--	<1	N.R.
Midwest[2] (reprocessing)	12/72	1	1	N.R.	2
Barnwell[3] (reprocessing)	4/74 (draft)	4	6	4	7

N.R. - Not Reported.

[1] This early draft EIS contains insufficient information to assess this dose in detail, but it is at least an order of magnitude greater than that from other comparable facilities.

[2] This facility is not now expected to become operational in the foreseeable future. A cow is occasionally pastured 1.5 mi. north of the site; the maximum estimated annual dose to a child's thyroid from milk supplied by such a cow is 7.4 mrem.

[3] Doses are to nearest individual.

mrem/yr, and for one, 4 mrem/yr are expected. Maximum doses due to liquid effluents display a similar pattern; the handful of doses shown that are significantly greater than 1 mrem/yr are calculated for the highly unlikely situation of individuals postulated to derive a major portion of their annual animal protein diet from fish grown directly in the undiluted effluent from the site. (Such situations, although perhaps theoretically possible, have not been observed, are not anticipated to actually occur, and could be avoided, if necessary, by restricting fishing at effluent discharge outlets.) Similarly, no individual is estimated to receive a dose as great as 1 mrem/yr due to gamma radiation from the combined impact of all facilities at any site. Finally, 90 percent of sites anticipate doses to a child's thyroid due to ingestion of milk at the nearest farm no greater than 10 mrem/yr. The single facility exceeding 15 mrem/yr could control 98 percent of its projected releases through simple modifications of the handling of untreated air ejector and steam generator blowdown effluents (27).

Table 5 demonstrates that 80 percent of the 31 sites containing BWR's anticipate maximum whole body doses from gaseous releases no greater than 2 mrem/yr, and that all but one will not exceed 5 mrem/yr. That site (Peach Bottom) predicts 8 mrem/yr at its nearest boundary for fulltime year-round unsheltered occupancy. The actual dose at the nearest residence would be significantly lower. Doses from liquid effluents are smaller, with 90 percent estimating 1 mrem/yr or less and no site exceeding 4 mrem/yr.

Doses due to gamma radiation originating onsite can be significant at BWR sites because of the circulation of activation-produced nitrogen-16 through the turbines in this reactor design. Careful design of shielding and turbine location relative to the site boundary and topographical features is required. In spite of this, only two BWR sites project boundary doses significantly greater than 5 mrem/yr to individuals. In one of these cases (Nine Mile Point) the dose can be reduced by restricting boating near the discharge canal; in the other (Bailly) the dose is to steel workers, not permanent residents, on an adjacent site, and appears to be unnecessarily high.

Of all the effluents from power reactors, iodine releases from BWR's represent the greatest potential source of maximum exposure to individuals. Although 70 percent of sites have projected maximum thyroid doses at the nearest farm of less than 10 mrem/yr, five estimate doses between 20 and 30 mrem/yr, and one projects doses significantly greater. The principal potential source contributing to all potential doses that are greater than 10 mrem/yr is iodine released from the turbine building vent (28). Treatment of this source term is possible, but is made more difficult by the large volume of air released from the turbine building. Selective treatment of the largest sources in the turbine building is possible, however, at reasonable cost, and is incorporated in a number of recent designs (29). The need for such treatment must be weighed, nonetheless, in the light of the results of field measurements of potential doses to the thyroid discussed below in Section C.

Table 6 summarizes conclusions on anticipated doses to the public due to operation of fuel cycle facilities other than reactors from environmental impact statements. It is far less extensive than that available for reactors, but represents the projected impact of facilities typical of modern practice. Significant, but relatively small doses are projected to the lung and bone at mills and fuel reprocessing, as well as to the thyroid at fuel reprocessing. The single instance of a projected dose significantly exceeding 10 mrem/yr is for a facility not projecting use of cost-effective levels of particulate control (30).

C. FIELD MEASUREMENTS OF ENVIRONMENTAL IMPACT

The oldest commercial power reactor, Dresden 1, commenced operation over fifteen years ago, in October 1959. By the end of 1972, there were 26 commercial power reactors in operation at 22 different sites, and in 1973, ten more reactors commenced operation. These utilities submit to the AEC (now the NRC) reports of actual releases on at least a semi-annual basis. These are reviewed for accuracy and published annually. In addition, EPA and its predecessor organizations have conducted detailed surveillance programs at selected facilities. These studies have consistently confirmed the accuracy of reported effluents of noble gases and liquids and the potential doses associated with these, but appear to reveal significantly lower potential thyroid doses than would be expected from reported releases using commonly employed modeling techniques and parameters for environmental pathways.

Table 7 shows calculated maximum doses at the site boundary for the reported releases of noble gases from operating reactor facilities for the years 1972, 1973, and 1974 (31). In almost all cases, actual releases were less than those assumed for the model-based calculations discussed in Sections A and B above. Figure 5, which is taken from a recent EPA report (32), shows the distribution of these releases for all BWR's commencing operation within the past decade as well as that assumed for the model calculations of the preceding sections. A similar figure is not available for PWR's due to their extremely low levels of reported releases. It can be seen from the figure that the average facility experienced releases a factor of 3 lower than the model assumptions, and that all facilities were at least 35 percent lower.

The doses shown in Table 7 are expected, on the basis of field experience, to fairly accurately represent actual doses that would be received by a hypothetical individual located at a reactor site boundary in the prevailing wind direction, year-round, and unshielded by any structure. Actual maximum doses to real individuals would, of course, be substantially lower. These doses have also been calculated for an

TABLE 7

CALCULATED DOSES FROM NOBLE GAS RELEASES AT OPERATING PLANTS (1972-74)

Facility (Site)	Start Up	Net Site Capacity [GW(e)]	Annual Output (% of Capacity)			Site Boundary Dose (mrem/yr)			Site Boundary Dose 80% Cap. (mrem/yr)			Site Boundary Dose w/Retrofit (mrem/yr)			D.F.[a]
PWR's			1972	1973	1974	1972	1973	1974	1972	1973	1974	1972	1973	1974	
Yankee Rowe	8/60	0.18	40	68	60	<1	<1	<1	<1	<1	<1	N.A.	N.A.	N.A.	N.A.
Indian Point 1 & 2	8/62,5/73	1.14	16	24	50	<1	<1	1	[b]	<1	2	"	"	"	"
San Onofre 1	6/67	0.43	74	60	84	3	2	<1	3	2	<1	"	"	"	"
Haddam Neck	7/67	0.58	85	46	89	<1	<1	<1	<1	<1	<1	"	"	"	"
R. E. Ginna	11/69	0.47	57	87	52	2	<1	<1	3	<1	<1	"	"	"	"
Point Beach 1 & 2	11/70,5/72	0.99	70	67	77	<1	<1	2	<1	<1	2	"	"	"	"
H. B. Robinson	9/70	0.70	72	82	87	<1	<1	<1	<1	<1	<1	"	"	"	"
Palisades	5/71	0.70	32	41	1	<1	<1	<1	<1	<1	[b]	"	"	—	"
Surry 1 & 2	7/72,3/73	1.58	6	65	45	<1	<1	8[c]	[b]	<1	15[c]	—	"	"	"
Turkey Point 3 & 4	10/72,6/73	1.39	—	62	66	—	<1	<1	—	<1	<1	—	"	"	"
Maine Yankee	10/72	0.79	7	58	52	<1	<1	<1	[b]	<1	<1	—	"	"	"
Oconee 1, 2, & 3	4/73,11/73,9/74	0.88	—	47	52	—	<1	3	—	2	5	—	"	"	"
Zion 1 & 2	6/73,12/73	1.05	—	22	39	—	<1	UA	—	<1	UA	—	"	—	"
Ft. Calhoun	8/73	0.46	—	42	60	—	<1	<1	—	<1	<1	—	"	—	"

N.A. = Not Applicable. UA = Unavailable.

[a] Decontamination factor of system augment committed by facility. No D.F.'s are listed since all existing facilities project releases of <1 mrem/yr.

[b] Not projected, due to the low fraction of capacity utilized.

[c] Unusual high dose due to operating problems with recombiner which resulted in shorter holdup times and higher than normal releases.

TABLE 7

(continued)

CALCULATED DOSES FROM NOBLE GAS RELEASES AT OPERATING PLANTS (1972-74)

Facility (Site)	Start Up	Net Site Capacity [GW(e)]	Annual Output (% of Capacity)			Site Boundary Dose (mrem/yr)			Site Boundary Dose 80% Cap. (mrem/yr)			Site Boundary Dose w/Retrofit (mrem/yr)			D.F.[1]
BWR's			1972	1973	1974	1972	1973	1974	1972	1973	1974	1972	1973	1974	
Dresden 1	10/59	0.20	65	33	21	13	12	<1	16	29	5	<1	<1	<1	180
Big Rock Point	9/62	0.07	57	68	54	5	4	3	8	5	5	<1	<1	<1	40[2]
Humbolt Bay	2/63	0.07	62	77	67	67	47	77	87	49	92	2	<1	2	40[2]
LaCrosse	7/67	0.05	60	46	79	<1	3	2	<1	5	<1	<1	<1	<1	100
Oyster Creek	5/69	0.64	78	64	67	37	32	11	47	40	13	1	1	<1	40
Nine Mile Point	9/69	0.63	59	68	62	11	22	16	15	26	20	<1	<1	<1	75
Dresden 2 & 3	1/70,1/71	1.62	57	64	48	2	5	4	3	6	6	<1	<1	<1	40
Millstone 1	10/70	0.65	55	34	63	8	2	23	12	5	29	2	<1	4	8
Monticello	12/70	0.55	75	68	62	30	31	67	32	36	86	<1	1	2	40
Quad Cities 1 & 2	10/71,4/72	1.60	28	73	57	<1	4	5	3	4	7	<1	<1	<1	16
Vermont Yankee	3/72	0.51	10	44	56	3	4	1	25	7	2	1	<1	—	>20
Pilgrim 1	6/72	0.66	15	71	34	<1	2	5	<1	2	11	<1	<1	<1	>40

[1] Decontamination factor of system augment committed by facility.

[2] No commitment for retrofit made. A minimum augment has been assumed (recombiner plus 1-day holdup) beyond 20-minute holdup and release via the existing stack.

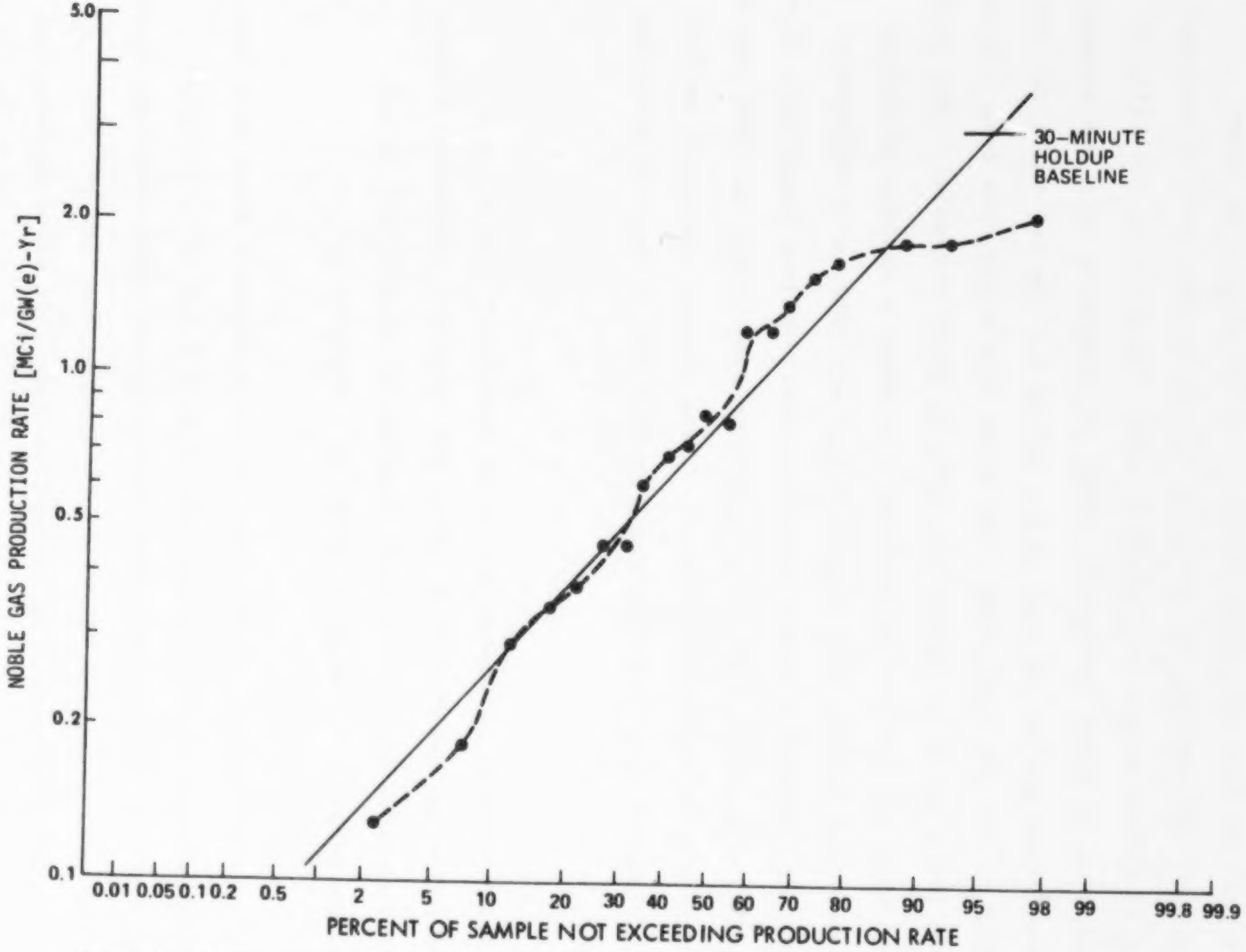


Figure 5. Distribution of noble gas releases in 1971-73 for boiling water reactors that commenced operation after 1968. The solid line is a fitted log normal distribution.

assumed year of full operation (taken to be 80 percent of rated capacity, on the average, on an annual basis) at the level of effluent control in effect during 1972 through 1974. Finally, on the basis of the retrofits of these facilities presently committed (all are scheduled to be completed within the next year, except for the two small old BWR's indicated as not yet committed), the doses that would have been observed in these years if the retrofits had been in place are shown. The data indicate that all but one PWR currently produces a maximum potential fence post dose 5 mrem/yr or less and that all BWR's with currently committed (or assumed minimum) retrofits would deliver fence post doses of 4 mrem/yr or less. The single anomolous case (Surry in 1974) was due to a breakdown in control equipment. These results appear to confirm the conservative nature of the model projections of the two preceding sections.

Liquid pathway releases from these facilities result in much smaller potential doses than do noble gas releases. Detailed studies of several operating facilities have revealed no actual dose to any individual from this pathway as great as 1 mrem/yr (33).

Studies of iodine pathways and potential thyroid doses have been conducted jointly by EPA and AEC (now ERDA and NRC) over the past several years at the Dresden, Monticello, Oyster Creek, and Quad Cities sites (34). Although atmospheric fallout from bomb testing has prevented the accumulation of definitive long-term measurements, the available results present a consistent picture of iodine concentrations in milk significantly less than those projected by models for the milk pathway used for most of the environmental analyses reported above. The difficulty appears to arise from inadequate assumptions regarding the input parameters of the model for airborne transport of iodine, although this is by no means definitively established and such other factors as the influence of wash-out, chemical form of the iodine, and pasture retention factors are also in question. Regardless of the exact cause of the discrepancy, the measurements at these facilities are consistent, and there is no known data in contradiction. The data for Monticello, Dresden, and Quad Cities are the most complete, and at pastures near each of these sites the concentrations of radioiodine in milk that were observed would lead to maximum thyroid doses to infants of a few tenths of a mrem/yr per curie of iodine-131 released annually to the environment from the site.

The results of these studies were used to project the expected maximum doses to a child's thyroid at the nearest pasture at all but 2 of the 12 BWR sites reporting releases in 1972 and 1973. (The locations of pastures and meteorological characteristics for two small, atypical BWR's, Humbolt Bay and Big Rock Point, were not available.) These projections were obtained by normalizing the meteorological characteristics for the nearest pasture and the actual releases of each facility to the same quantities for Monticello and Quad Cities, and projecting the resulting doses for operation of each facility at 80 percent of full capacity. The results indicate that, based on actual releases reported in 1972 and 1973 by these operating facilities and the field measurements conducted in these years at the two facilities studied in detail, no facility had projected maximum potential thyroid doses to an infant as great as 1 mrem/yr, in either year, for assumed average annual operation at 80 percent of full rated capacity.

Field measurements at other fuel cycle facilities are very sparse. In 1968 DHEW completed a study at a fuel reprocessing facility (35); this facility is not now in operation and is not representative of the performance of current technology. The study indicated that maximum potential individual whole body doses of up to several hundred mrem/yr and comparable maximum organ doses to the bone were possible at that time due to ingestion of deer (which had access to the site) and fish raised in the plant effluent. Access to such sources of intake would not be possible at a modern facility of this type.

D. THE PROPOSED STANDARDS

Numerical values to limit public exposure and environmental contamination by long-lived radioactive materials were selected by first determining the dose levels achievable using cost-effective levels of effluent control for the reduction of total population impact, and then by further considering the acceptability of the resulting maximum individual doses and, finally, in addition, the potential for long-term environmental contamination. The methodology has been described in Chapter IV in general terms, and specifics are as developed above in Section V-A. The resulting levels are shown in Table 3, and are confirmed as representative of levels achievable by real sites and by actual operations by the data developed in Sections V-B and V-C above. To these levels was added a margin to provide for operating flexibility to accommodate minor deviations from anticipated performance levels, differences in specific parameters of actual sites, and the possibly somewhat greater impact of larger numbers of facilities on larger sites. The standards were chosen so as to limit the quantity discharged or the maximum individual annual dose rate depending upon whether the radioactive materials concerned were long-lived or short-lived, respectively. Table 8 summarizes the numerical values of the standards proposed on these bases.

The proposed standard for maximum annual whole body dose to any individual limits the combined external and internal dose due to short-lived gaseous and liquid effluents as well as to exposure to gamma radiation originating from all operations of the fuel cycle to 25 mrem/yr. As shown in the preceding sections, such a value is easily satisfied by levels of control that are cost-effective for the risk reduction achieved; is achievable at all sites for which environmental statements have been filed; and, on the basis of operating experience at existing sites, can be readily achieved in practice. This value has

TABLE 8

THE PROPOSED STANDARDS FOR NORMAL OPERATIONS OF THE URANIUM FUEL CYCLE

A. Individual Dose Limits

1. Whole body	25 millirems/year
2. Thyroid	75 millirems/year
3. Other organs[*]	25 millirems/year

B. Limits for Long-Lived Radionuclides

1. Krypton-85	50,000 curies/gigawatt-year
2. Iodine-129	5 millicuries/gigawatt-year
3. Transuranics[**]	0.5 millicuries/gigawatt-year

C. Variances

At the discretion of the regulatory agency (licensor) for temporary and unusual operating circumstances to insure orderly delivery of electrical power.

D. Effective Dates

1. Two years, except
2. 1983 for krypton-85 and iodine-129.

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[*] Any human organ except the dermis, epidermis, or cornea.

[**] Limited to alpha-emitters with half-lives greater than one year.

been chosen to provide a reasonable margin of operating flexibility beyond the 1-5 mrem/yr projected for most sites operating with levels of control that are cost-effective. It will also provide an ample margin for sites with larger numbers of reactors than two (see Section VI-F). Finally, the combined impact of a fuel reprocessing facility, if added to that at any reactor site, is judged to be such that the standard could continue to be met by levels of control that are cost-effective. This case of mixed types of facilities on a single site is judged to represent the worst case reasonably anticipatable.

The appropriate level for a standard limiting the maximum annual thyroid dose of individuals is not as easy to select. On the basis of existing field measurements a value much less than that proposed would appear to be appropriate. In addition, the level of control assumed necessary by the NRC in recent licensing actions on the basis of model projections appears to be somewhat greater than that justified on the basis of cost-effectiveness of risk reduction to the entire population alone. This is because only a small number of individuals are potentially subject to relatively high doses. If actual doses are, indeed, as low as those indicated by the limited existing number of field measurements, the degree of control assumed necessary may be unwarranted. However, the proposed standard has not been based upon the evidence of field measurements, except to the degree that they indicate that the very high doses projected in a few instances are unrealistic. The standard has been chosen, instead, so as to reflect a level of biological risk comparable, to the extent that current capability for risk estimation permits, with that represented by the standard for whole body dose. This level (75 mrem/yr) should be readily achievable by all sites using no more control equipment than is now required by normal licensing procedures.

Doses to other organs may be maintained within 25 mrem/yr using economical and readily available controls for limiting environmental releases. These doses arise principally from exposure of lung and bone as a result of airborne effluents from fuel supply facilities. The controls required to achieve the necessary reduction of effluents are in common use in other industries, and include such methods as wet and venturi scrubbers and HEPA filters for the removal of particulates, and on-site dust control through the use of chemicals and other materials to prevent wind erosion. In some cases the achievement of doses within 25 mrem/yr may not be cost-effective, because of the small populations involved near many fuel supply facilities. However, because of the low cost of these control measures, individual doses of higher magnitude than those permitted by the proposed standards are not judged to be necessary or reasonable.

The proposed standards for long-lived materials fall into two categories: those which can be achieved using currently available methods for control of environmental releases, and those that require use of methods that have been demonstrated on a laboratory or larger scale, but have not yet achieved routine use. In the former case, exemplified by the standard for plutonium and other transuranics, the standard limits the environmental burden to a level consistent with that reasonably achievable using the best available control methods. This level of control also satisfies the criteria for cost-effectiveness developed in Section V-A. In the latter case, that of the proposed standards for krypton-85 and iodine-129, the limiting levels of environmental burdens specified are not those achievable by best available performance, but instead by minimum performance reasonably anticipated from these new systems. Again, the costs of these systems are judged to be justified by the reduction of potential health impact achieved at these levels of performance. (See also, in this regard, the expanded discussion of the costs and benefits of krypton-85 control in Section VIII-B). As experience is gained concerning the ability of the industry to limit fuel cycle releases of these materials to the environment the Agency will consider the need for revised levels for maximum environmental burdens of these persistent radionuclides.

Similarly, as knowledge becomes available concerning the capability of technology to limit environmental releases of tritium and carbon-14, the appropriate levels of environmental burdens of these radionuclides will be carefully considered by the Agency. However, the knowledge base now available is considered inadequate for such a determination, and no standards are presently proposed for these radionuclides.

The proposed standards are designed to govern regulation of the industry under normal operation, and therefore a variance is provided, to be exercised by the regulatory agency, to accommodate unusual and temporary conditions of facility operations which deviate significantly from such planned normal operation. This provision is important because the standards, although they should be readily satisfied with an adequate margin of flexibility under normal conditions, are not intended to provide for the operational flexibility required under unusual operating situations. Unusual conditions have not been addressed by these standards, which are intended to define environmentally acceptable levels of normal operation only, and not acceptable levels of unusual operation. It is anticipated, however, that although such unusual operation may occur, at some facilities more often than at others, every effort will be made to minimize such operation by the regulatory agency.

The proposed standards for maximum doses to individuals were derived through consideration of the doses arising from effluents released from single sites. However, since large numbers of sites are projected for single geographical regions in several parts of the country, the possibility of additive doses exceeding the maximum limits for individuals due to the combined effect of effluents from many sites must also be considered. This problem may be conceptualized as having two components. The first is the possibility that two sites may be sufficiently close to each other that the maximum dose to an individual from one is appreciably increased by the other. The second is the possibility that the combined effect of all of a large number of sites in a particular geographical region may give rise to a general increase in dose levels of significance compared to the maximum dose from any single site.

Because of the importance of specific meteorological and geographical parameters, the first possibility is best considered on the basis of real cases. The largest potential contribution to individual dose is via airborne releases. Since doses due to such releases generally fall off to less than 10 percent of their maximum values within 10 to 20 kilometers, only sites separated by less than 20 km were considered. There are presently only 3 pairs of such sites projected through the year 1985. These were each examined using the specific meteorological parameters characteristic of these sites. The maximum increases in maximum doses are shown in Table 9. In no case is the increase as great as 20 percent. Given the margin of flexibility available in the capability of effluent control systems, this modest overlap of doses is not judged to pose any difficulty with respect to compliance with the proposed standard.

The second possibility, that of a general increase due to the impact of large numbers of facilities in a region, has been extensively examined in a recent AEC study of the implications of projected future nuclear facilities in the upper Mississippi river basin (36). This study, which was carried out, among other objectives, to assist EPA in

TABLE 9

POTENTIAL INCREMENTAL DOSES DUE TO OVERLAP OF EXPOSURES TO AIRBORNE EFFLUENTS AT CLOSEST PRESENTLY PROJECTED NUCLEAR FACILITY SITES

Site Designations	Distance Between Sites (km)	Maximum Dose†
Peach Bottom - Fulton	2.4	1.20
Point Beach - Kewaunee	7.0	1.06
Hope Creek, Salem†† - Summit	14.5	<1.04

†Expressed as the ratio of the maximum dose for the two sites together to the maximum dose in the absence of the second site. In each case the maximum dose due to overlap occurs at or near the point where the maximum dose due to a single site would occur.

††Hope Creek and Salem facilities share a common site.

evaluating the environmental aspects of expanded use of nuclear power, analyzes the potential combined impact of approximately 350 reactor facilities and 9 fuel reprocessing facilities projected for this river basin by the year 2000. The study divided the region into 300 areas, almost as many areas as there are individual reactors projected for the region. The analysis shows that in none of these areas does the projected average dose to individuals exceed 1.2 mrem/yr. The average for the entire region is less than 0.2 mrem/yr. It should be noted that these are average, rather than maximum, doses, so that these results do not specify the maximum doses projected in each subarea, but rather the sum of the general impact of the many sites outside each area plus the average local impact of any single sites within the area. A substantial portion of even these small doses must necessarily arise from local contributions from within each area. The analysis included a detailed treatment of all pathways, including air, water, and foodstuffs. Well over 90 percent of all doses was found to result from pathways involving airborne transport of effluents, justifying, therefore, the above assumption that airborne effluents are the primary source of doses. It is concluded that any general increase in radiation doses from regional contributions will be small compared to the maximum individual doses to which the proposed standard applies.

VI. ANTICIPATED IMPACT OF THE PROPOSED ACTION

The proposed environmental radiation standards for the uranium fuel cycle are anticipated to have impacts on long-term contamination of the environment, on public health, and on the economic cost of producing electrical energy. The impact of the proposed standards has been assessed relative to that associated with current standards under which the nuclear industry has evolved up to the present time. Since the proposed standards are more restrictive than current standards their environmental and public health impacts will logically be positive and not adverse in nature. On the other hand, achievement of improved levels of protection of public health and the environment will require controls that will result in increased costs which must be reflected in energy prices. Standards could also have implications for Federal and State agencies charged with the responsibility of regulating the industry (or operating facilities that are part of the fuel cycle), on the distribution of pollutants between the various environmental media, for the number of uranium fuel cycle facilities that can be operated at single or contiguous sites, and even on the mix of nuclear and non-nuclear fuels used for the production of electricity. These real and potential impacts are considered in turn in the following sections.

The projection of total impact is, of course, dependent upon forcasts of the growth of the industry. For the purpose of these analyses it has been assumed that the industry will grow at a rate consistent with the annual production of 1000 gigawatt-years of power in 25 years, or approximately by the year 2000. This level of output is consistent with the goal set in 1975 by the President's program for energy independence (41) and the midrange projections of the Atomic Energy Commission (11) when this statement was prepared. However, more recent assessments indicate that this level of output may not be achieved by the year 2000 (6). The projections of impact made below would hold, approximately, for achievement of this level of output by a later (or earlier) year, or can be scaled proportionately to obtain an assessment of impact for other assumed levels of power production by the year 2000.

A. ENVIRONMENTAL IMPACT

The environmental impact of fuel cycle operations has been considered from the point of view of long-term irreversible commitments of radioactive pollutants to the planet's terrestrial, atmospheric, and aquatic environments. In the next section, the public health implication of these commitments, as well as that of short-lived materials, is considered. That consideration of public health impact is limited, however, to potential health effects initiated by exposure to these materials during the first 100 years following their introduction to the environment only, and cannot, because of our inadequate understanding of their long-term behavior, comprehend their full potential impact. Effects on other life forms have not been assessed in this statement, since they are not expected to be significant at levels adequate for protection of human populations (37).

Environmental burdens of tritium, carbon-14, krypton-85, iodine-129, and plutonium and other transuranics were examined for projected normal releases over the next 50 years from the U.S. nuclear power industry operating under existing standards and regulations (13). The results of these analyses are shown in Figures 6-10. For those radionuclides now released without any restriction, the levels that could be achieved with and without the proposed standards are shown. In cases where releases of these materials are currently limited, projections for each of several levels of control are shown.

These projections demonstrate several significant characteristics. In all cases, existing environmental burdens due to nuclear power operations are small, and in all cases rapid increases are anticipated in the near future at current levels of control. The public health significance of these increased burdens, as assessed in the next section of this statement for the first 100 years following release, is significant for all of these radionuclides and is particularly large for tritium, carbon-14, and krypton-85. The total significance of

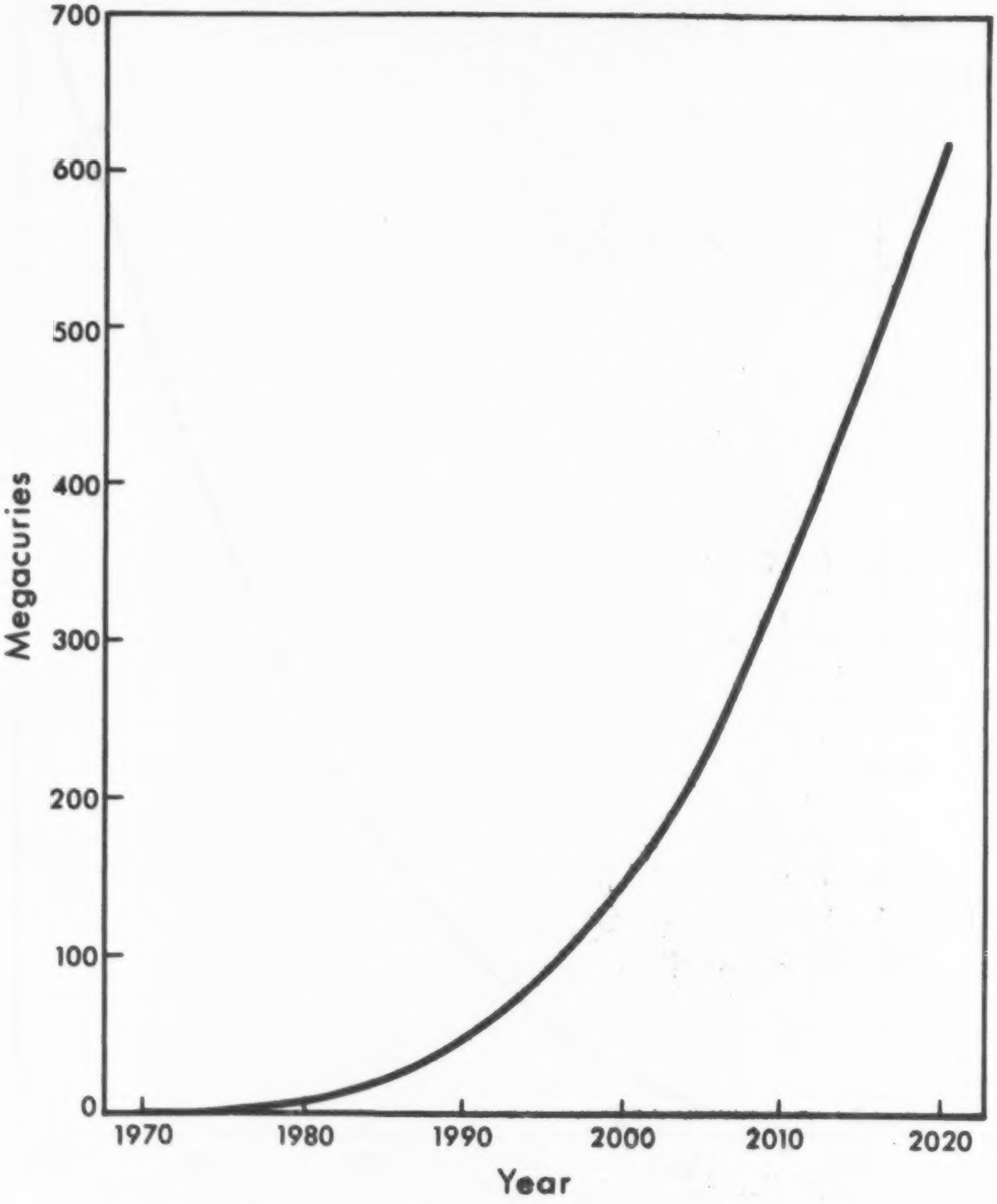

Figure 6. Projected Environmental Burden of Tritium from the United States Nuclear Power Industry.

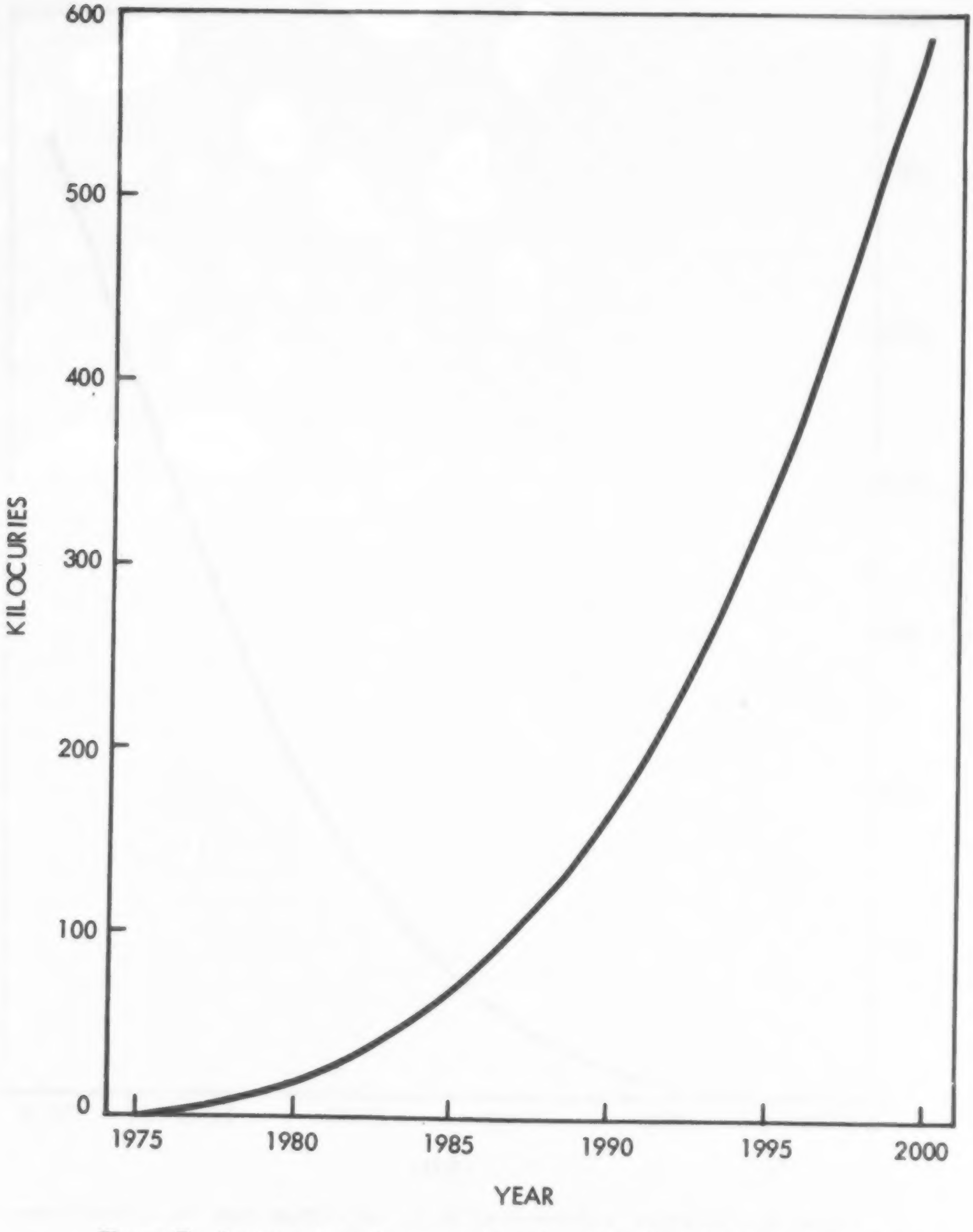

Figure 7. Projected environmental burden of carbon-14 from the United States nuclear power industry.

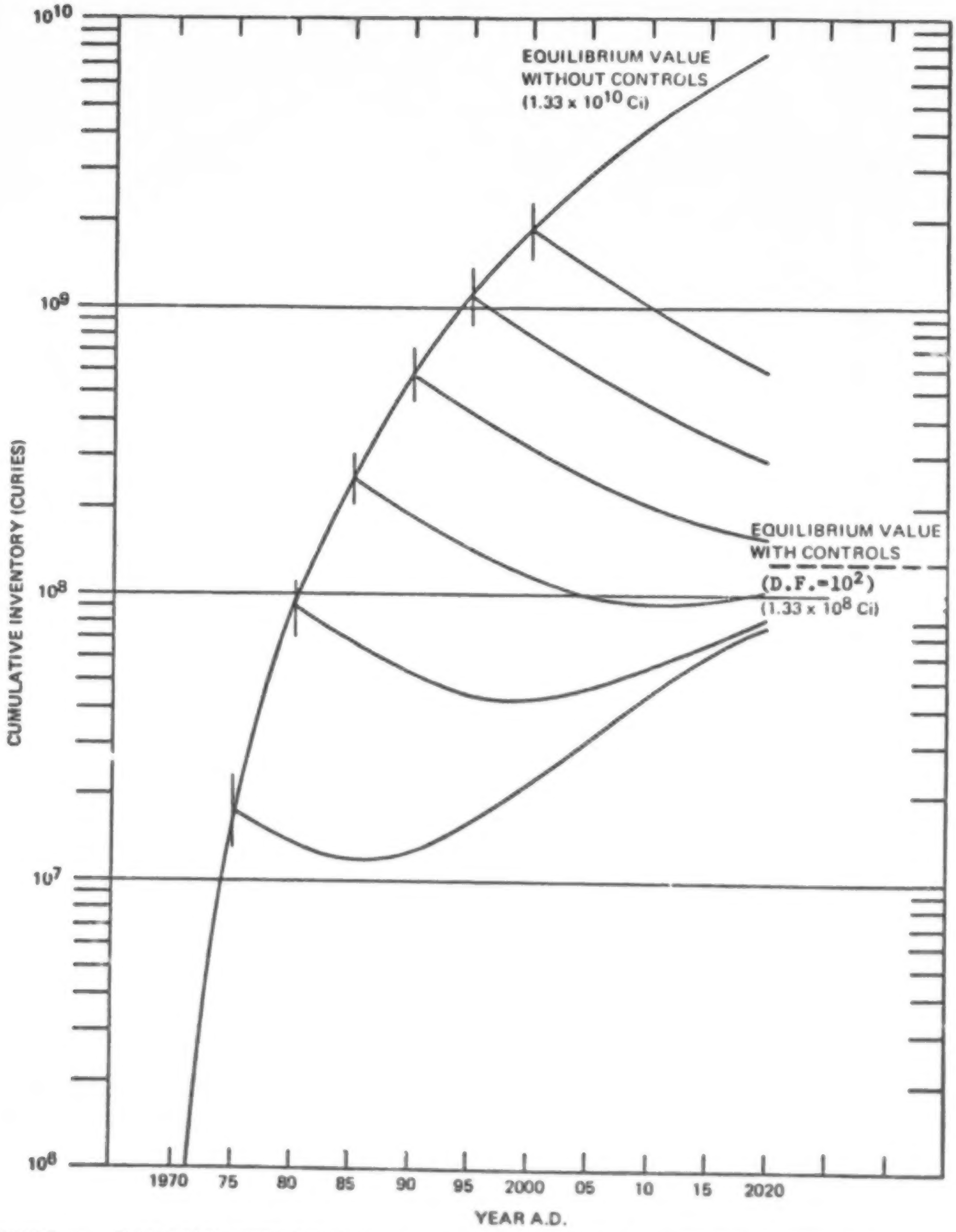

FIGURE 8. PROJECTED ENVIRONMENTAL BURDENS OF KRYPTON-85 FROM THE UNITED STATES NUCLEAR POWER INDUSTRY FOR CONTROL INITIATED IN VARIOUS YEARS. THE EQUILIBRIUM VALUES ARE THOSE FOR MAXIMUM POWER PRODUCTION EQUAL TO THAT PROJECTED FOR THE YEAR 2020.

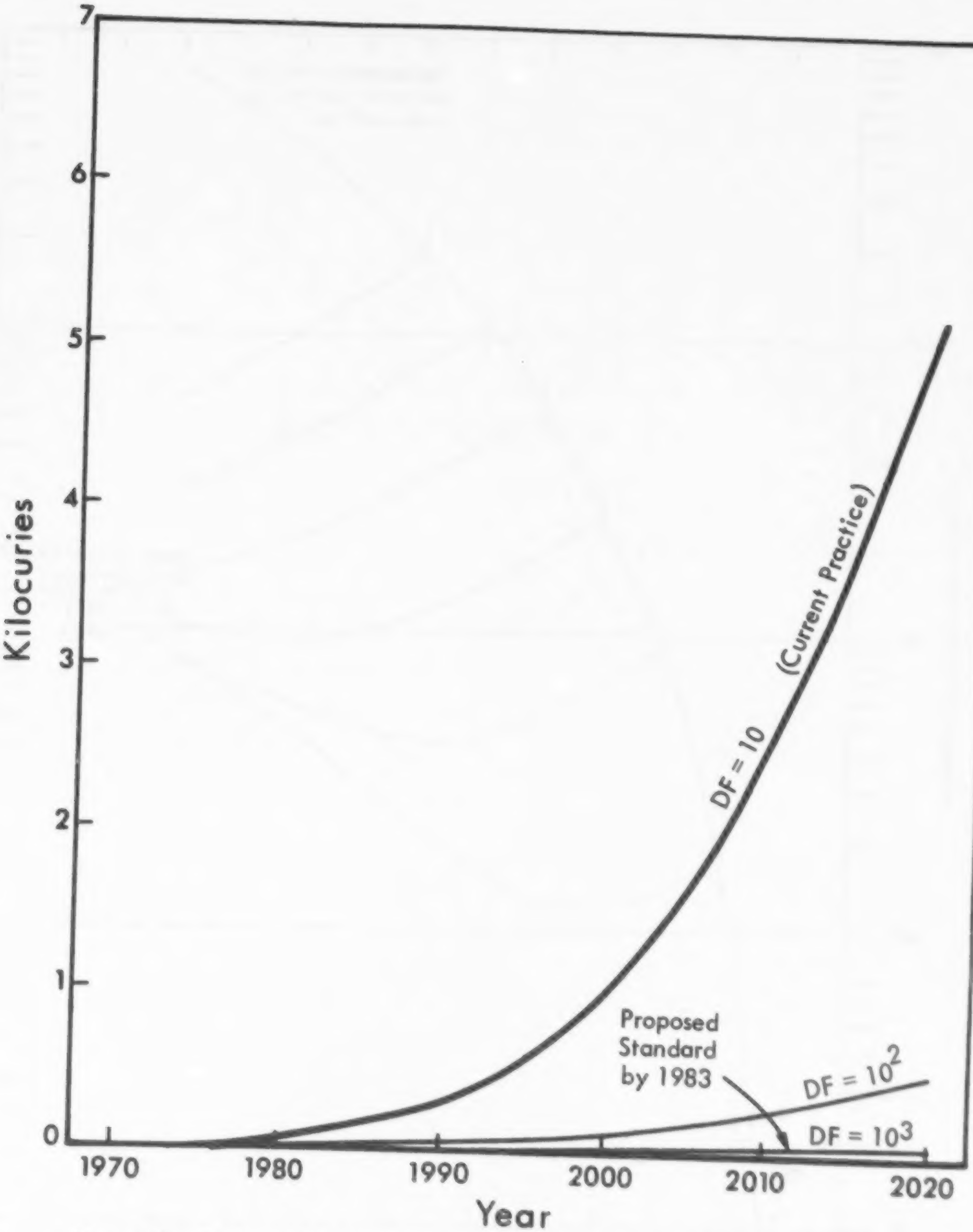

Figure 9. Projected Environmental Burdens of Iodine-129 from the United States Nuclear Power Industry at various levels of control

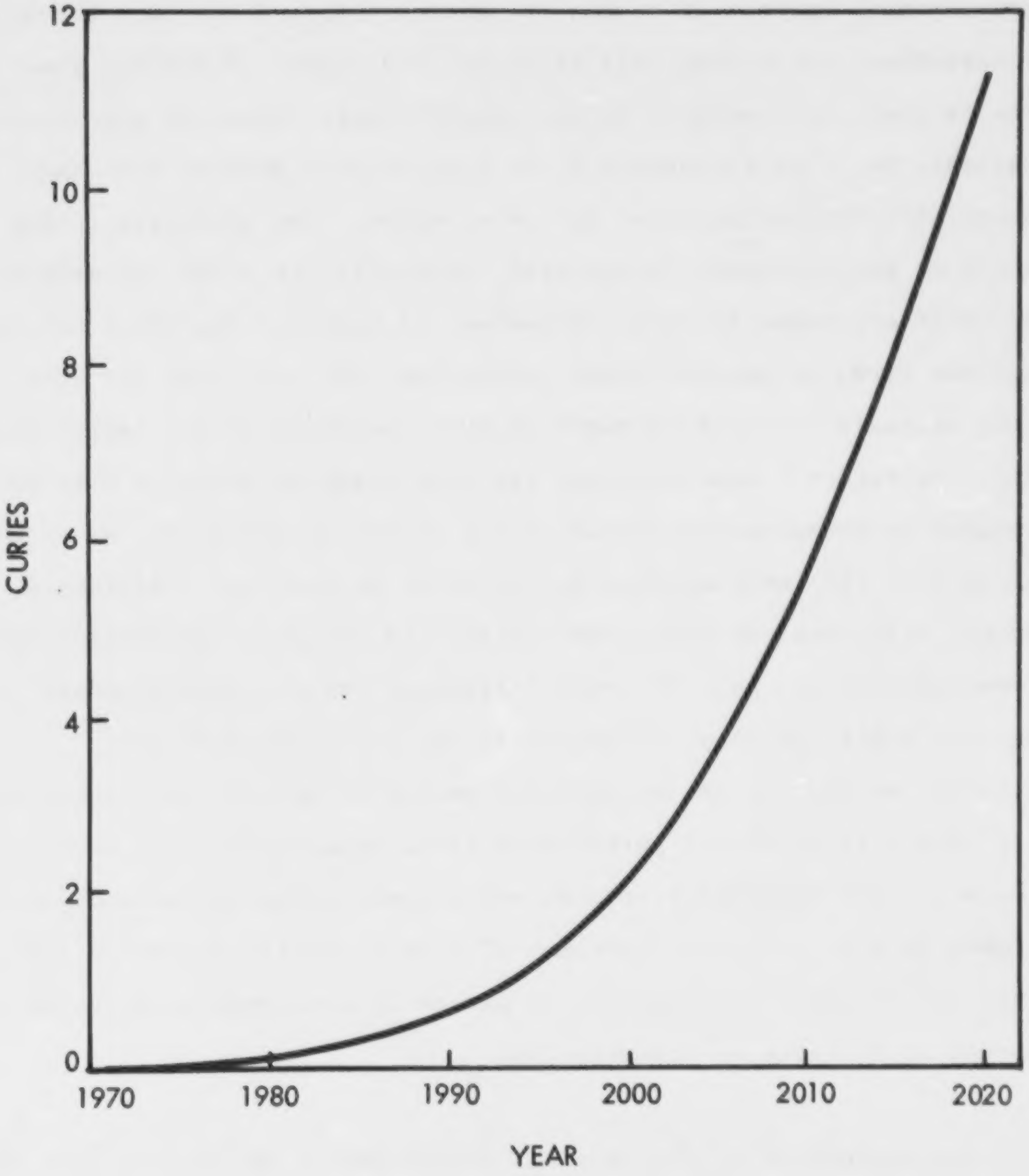

Figure 10. Projected environmental burden of alpha-emitting transuranics with half-lives greater than one year, from the United States nuclear power industry, assuming release of 10^{-9} of inventory and operation with uranium fuel only.

environmental burdens of carbon-14, iodine-129, and the long-lived transuranics, which have half-lives of 5700 years, 17 million years and from 18 years to 2 million years, respectively, cannot be quantitatively assessed, but must be assumed to be considerably greater than that anticipated during the first 100 years alone. The potential future impact of the release of krypton-85, especially if other releases around the world are added to these estimates, is strongly dependent not only upon the level of nuclear power production, but also upon the year in which controls to limit releases of this radionuclide are implemented (38). As Figure 8 demonstrates, implementation of controls with an attained decontamination factor (D.F.) of 100 in the early 1980's would insure that the environmental burden never exceeds the equilibrium burden, with such controls, associated with any power production level projected over the next 50 years. Although the proposed standard requires a D.F. of only approximately 10, it is expected that installation and use of the controls needed to satisfy this requirement will result in an actual performance level approaching that shown in Figure 8. The proposed standards would limit projected environmental burdens of iodine-129 to 1 percent of that currently projected (39), and would also require continuation of presently used best practicable control of releases of transuranics.

The admonition of the National Environmental Policy Act (26) that "...it is the continuing responsibility of the Federal Government to use all practicable means..to the end that the Nation may...fulfill the responsibilities of each generation as trustee of the environment for succeeding generations..." is particularly germane to consideration of these long-term environmental pollutants. At currently projected levels of fuel cycle operations it is clear that the potential for future radiation effects is substantial in the absence of standards to limit environmental burdens of these materials. This goal is not satisfied by these standards for releases of tritium and carbon-14 only because control technologies for these materials are not yet commercially available.

B. HEALTH IMPACT

The anticipated impact of these standards on the potential for effects on public health is shown in Table 10. These estimates of potential health effects are limited to cancers (including leukemia), and serious genetic effects (these include congenital abnormalities leading to serious disability, and increases in diseases that are specifically genetic, such as certain forms of mental defects, dwarfism, diabetes, schizophrenia, epilepsy, and anemia). The genetically-related component of diseases such as heart diseases, ulcers, and cancer as well as more general increases in the level of ill-health are omitted from estimates of genetic effects, as are effects on growth and development, because of the wide range of uncertainty in existing estimates of their importance, coupled with a judgment that their total impact is probably

TABLE 10

POTENTIAL HEALTH EFFECTS ATTRIBUTABLE TO OPERATION OF THE NUCLEAR FUEL CYCLE THROUGH THE YEAR 2000 AT VARIOUS ENVIRONMENTAL RADIATION PROTECTION LEVELS†

Type of Radioactive Material	Federal Radiation Guides	Current AEC Practice††	EPA Generally Applicable Standards††
1. Short-lived materials	34,000	170	160
2. Long-lived materials†††			
a. Controllable (^{85}Kr, ^{129}I, ^{239}Pu, etc.)	1,040	1,040	20
b. Tritium	440	440	440*
c. Carbon-14	12,000	12,000	12,000**

†These projections are based upon the linear nonthreshold assumption, which, at the current level of understanding of radiation effects in man, warrants use for determining public policy on radiation protection. It should be recognized, however, that these projections are not scientific estimates, but judgments based upon scientific data obtained under different conditions of exposure than those associated with nuclear fuel cycle operations. Health effects shown are limited to total cancers, including leukemias, and serious genetic diseases (see text). The entries are the predicted number of health effects attributable to releases from the U.S. nuclear industry by the year 2000. The projections assume that approximately 8300 GW(e)-yr of electric power will be produced by nuclear reactors in this period, based on AEC Case B projections (WASH-1139(74)). It is also assumed that all nuclear fuel cycles will operate at the same level of impact as the uranium fuel cycle.

††Assumes implementation of Appendix I as proposed in the Concluding Statement of the Regulatory Staff (February 20, 1974).

†††Effects are projected for the first 100 years following release only.

*The majority of this impact can be eliminated through implementation of the voloxidation process at fuel reprocessing, if current development efforts continue and are successful.

**About 60% of this impact may be eliminated as a by-product of the retention of krypton-85 at fuel reprocessing, however, knowledge concerning control of this source of health impact is currently limited.

no greater than that of those health effects that have been quantitatively considered. To the extent that other somatic and genetic effects are important, the present estimates of the impact of radioactive effluents on health are not conservative, although such effects are expected to be reduced by improved levels of effluent control in the same proportion as are those that have been quantified. In most instances, the numerical estimates of health effects were derived using the results of EPA's model projections of effluents and dose pathways for fuel cycle operations and health risk estimates from the recent National Academy of Sciences' report on this subject (14).

The Table 10 entries in the column labeled "Federal Radiation Guides" were derived assuming use of the minimum level of effluent control required to assure a dose no greater than 170 mrem/yr to individuals permanently residing at site boundaries. They do not represent the physically unrealizable assumption of 170 mrem/yr/individual to entire local, regional, or national populations. While these entries are representative of the levels of operation that are permitted by the current Federal Radiation Guides and reflected by the NRC's effluent standards in 10CFR20, it should be recognized that most current operations are conducted so as to maintain maximum doses well below these permitted levels. The proposed standards would, however, remove the possibility that these unnecessarily high levels of dose could continue to be sanctioned by license conditions for normal operations of any fuel cycle operations, as is now the case for all facilities except those reactors whose license conditions have been updated to reflect the guidance of Appendix I to 10CFR50.

The second column shows the reduction in potential effects that was achieved through application by the AEC of the Federal Radiation Guidance that annual doses to individuals be kept as far below the Radiation Protection Guides "as practicable." These entries also reflect the levels of potential impact that would have resulted from the guidance for design and operation of light-water-cooled reactors proposed by the AEC as Appendix I to 10CFR50, if it had been promulgated by NRC as proposed (40). An assessment of Appendix I as actually promulgated is more difficult because of the deletion of curie limits for radioiodines in airborne effluents and for radioactive materials in liquid effluents. However, it is anticipated, if Appendix I is implemented so as to maintain effluents sufficiently low as to insure that the design objectives are met in actual operating situations for all but temporary and unusual circumstances, that the level of potential impact should be essentially that projected for "proposed" Appendix I.

The final column shows the estimated levels of effects attributable to the industry operating under the proposed standards. The small reduction shown in the final column for short-lived materials occurs as a result of reductions in dose from components of the cycle other than reactors only, since it is assumed that the proposed standards would be satisfactorily implemented at reactors by the guidance contained in Appendix I.

The proposed standards would result in a reduction of approximately 1000 potential health effects due to releases of long-lived materials to the environment through the year 2000. The principal residual impact of the fuel cycle would then be that attributable to carbon-14 and tritium, and control of a substantial fraction of this impact may be achievable in the near future through inexpensive modification of systems that are installed to meet the requirements of the proposed standard for krypton. In any case, the Agency will closely follow the development of knowledge concerning control of these materials.

Figure 11 shows the projected growth of the potential health impact of these materials through the year 2000. The projections are for assumed operation of the industry using uranium fuel only, and also assume the achievement of an annual production of 1000 GW(e)-yr of electrical power by the year 2000. As pointed out above, although this level of output is consistent with the goal set in 1975 by the President's program for energy independence (41), recent projections indicate that this level of output may not be achieved by the year 2000. These projections would hold, approximately, for achievement of this level of output by a later year, or can be scaled proportionately for other assumed levels of power production in the year 2000.

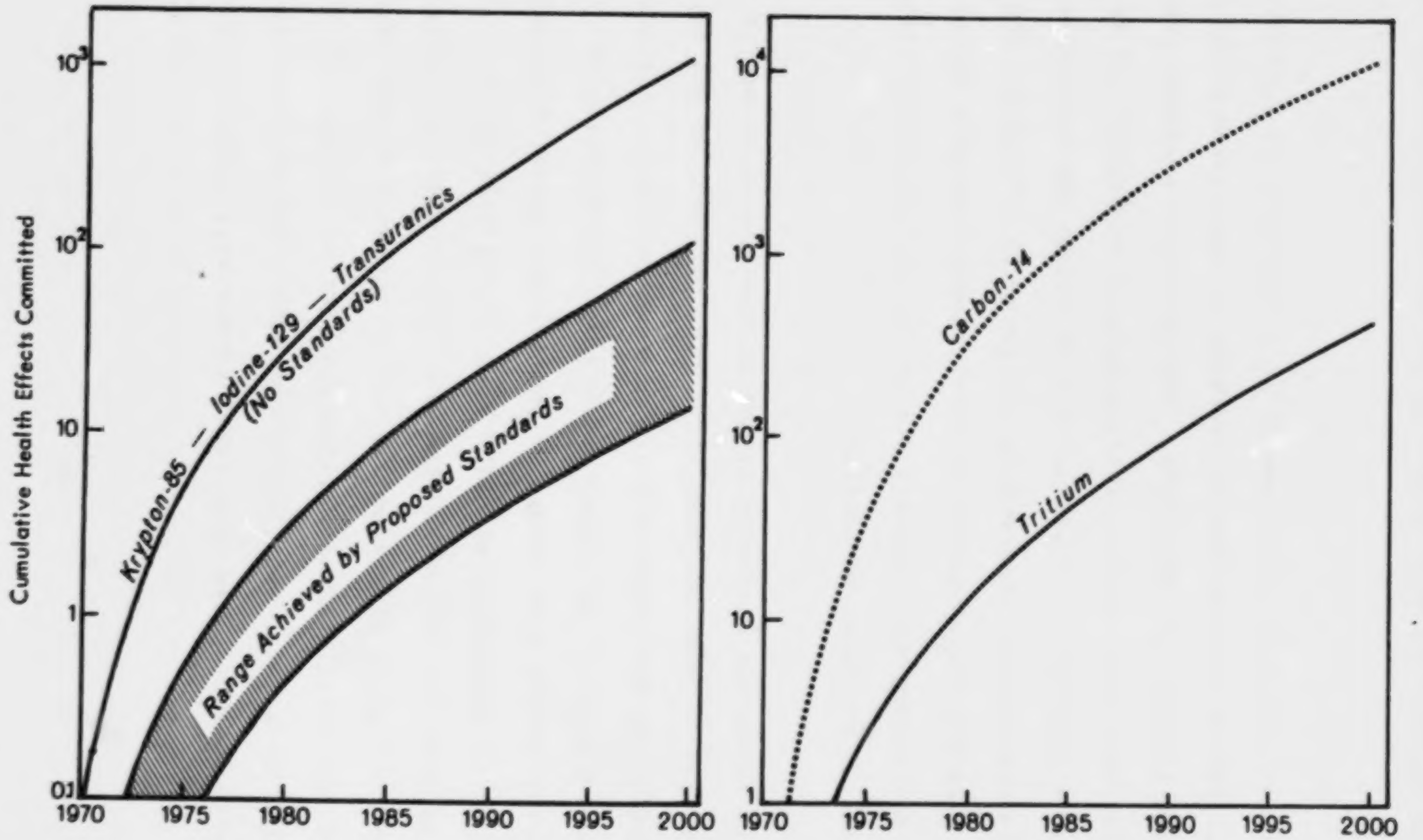

Figure 11. Projected health effects attributable to releases of long-lived radionuclides. Health effects are projected for 100 years following release only, and the exclusive use of uranium fuel is assumed.

C. ECONOMIC IMPACT

The economic impact of the costs imposed by these standards has been be considered from two viewpoints; first, is the cost reasonable for the protection received, and second, will the costs have any impact upon the ability of industry to supply needed power. The cost-effectiveness of the risk reduction achieved by the proposed standards was given careful consideration, as has been described in preceding sections of this statement. Most of the reduction in potential health effects required by these standards comes as a result of the reduction of environmental releases of long-lived materials. This reduction is achieved at a cost of no more than a few hundred thousand dollars per potential health effect averted (42), a rate of spending for public health protection less than that already in effect in the industry for other types of radioactive effluent control (50). This is because the proposed standards impose increased control requirements principally on effluents that can deliver doses to very large populations over long periods of time, instead of in areas where short-term doses to only a relatively few individuals near facilities can occur.

In November 1975, there were approximately 55 reactor units in operation, 86 under construction, 55 under construction permit review but not authorized for site work, 23 ordered, and 19 more planned for construction during the next 10 years, for a total of 238 units. The capital cost of a newly ordered one GW(e) reactor was estimated in 1972 to be on the order of 450 million dollars. Current estimates are considerably higher, and values of over 700 million dollars are now projected (43). The additional capital costs, beyond those incurred by practice employed in industrial operations prior to the proposal of Appendix I by the AEC, for control equipment required to meet the standards are estimated to be approximately 1.5 to 2.8 million dollars (1972 base) at a PWR and 6.2 to 7.6 million dollars at a BWR, for a 1 GW(e) facility. The range of values reflects the range of iodine control required at different sites. If it is assumed that the costs of effluent controls exhibits the same behavior as has the cost of reactors as a whole, it is clear that the capital cost of controls to meet the proposed standards is less than one percent of the capitol cost of pressurized water reactor and one to one and one-half percent of the capitol cost of a boiling water water reactor. The increased annual operating cost associated with these additional controls would be less than 1 percent for a PWR and perhaps as much as 5 percent for a BWR. The higher costs for BWR's are a reflection of a simpler basic design which produces, however, a considerably larger volume of effluents that must be treated. It should be particularly noted that these increased costs for reactors are required, independently of these EPA standards, by Appendix I as issued by the NRC in May 1975. Since this increase has already been anticipated by industry in its current designs and the NRC is currently implementing Appendix I in its license specifications, the proposed EPA standards would not, in any real sense, cause any increased expenditures at reactors. It should be noted that monitoring and reporting requirements would be essentially unchaged at reactors. The few minor additional costs are described in Section VIII-A.

The principal economic impact of the proposed standards is that they would require an approximately 10 percent increase in the capital costs of a fuel reprocessing plant, principally to remove krypton-85. The impact on the balance of other components of the fuel cycle is anticipated to be smaller. The present worth of new controls to meet the proposed standards at a fuel reprocessing facility is estimated as approximately 30 million dollars, or 0.7 million dollars per gigawatt(electric) of fuel cycle capacity served. The combined cost of controls at all other fuel supply and handling facilities is estimated to be no more than 0.3 million dollars per gigawatt(electric) of fuel cycle capacity served. Since fuel cycle costs not directly associated with the power reactor represent less that 20 percent of the total cost of power (44), the impact of these increased fuel supply and reprocessing costs on the cost of power is anticipated to be considerably less than 1 percent. This cost, even when added to increases in capital and operating costs for controls on the reactor required by Appendix I, is calculated to result in an overall impact of these standards on the cost of power that is still less than one percent of its total cost at the busbar from a PWR, and less than two percent from a BWR. Incremental costs to consumers will be a factor of two to four less than even these small amounts, due to the presence of large unaffected fixed costs for power transmission and distribution. It is concluded that the combined economic impact of these proposed standards and Appendix I will be small, and cannot realistically be anticipated to have any impact on the ability of the industry to supply electrical power.

D. ADMINISTRATIVE IMPACT

The Federal agency principally affected by these standards will be the Nuclear Regulatory Commission (NRC), which has the responsibility to insure adherence to EPA's environmental standards in its regulation of the individual facilities comprising the commercial nuclear power industry. The Energy Research and Development Administration (ERDA) will be affected to the extent that the uranium enrichment facilities operated by ERDA supply the commercial nuclear power industry and additional development and/or research associated with of effluent controls for krypton-85 and iodine-129 is carried out by ERDA laboratories. The Department of Transportation would also be affected to the extent that its regulations concern minimization of public doses due to shipments of spent fuel assemblies and high-level radioactive wastes.

It is unlikely that issuance of these environmental standards will cause any substantial impact due to the need for changes in licensing regulations for power reactors. In the case of reactors, the NRC recently issued new design and operating guidance (Appendix I to 10CFR50) which can, with certain minor modifications, be used immediately as regulatory implementation of these standards for reactors by NRC. These are discussed in Section VIII-A. The NRC announced, when it issued Appendix I to 10CFR50, that it would make any changes in that proposed guidance that would be required to conform to EPA standards. Since the standards proposed here for reactors do not require substantial modification of Appendix I, there should be no impact on NRC's regulatory process for power reactors that differs materially from that already required for implementation of Appendix I.

In the case of other components of the fuel cycle, the current regulatory situation is one of uncertainty and potential change. These facilities have generally operated within the numerical limits prescribed in 10CFR20 (which contains a detailed statement of the implications, isotope by isotope, of the current Federal Radiation Guides for maximum exposure of individuals) with no codification of numerical guidance for these activities of the lowest practical effluent levels. In May 1974, the AEC announced that it was undertaking rulemakings to determine "as low as practicable" design and operating conditions for several of these components of the cycle (45). To date, this guidance has not been issued. Issuance of these proposed standards by EPA should help to expedite promulgation of this "as low as practicable" guidance by NRC. To the extent that any environmental statement is required of the NRC for such new regulations, that process should be considerably simplified and shortened by the existence of these environmental standards, compared to the lengthy procedures now followed for developing regulations governing environmental releases from the industry. The establishment of technical specifications to insure conformance with these standards at facilities other than reactors will be required. However, this process should not require technical analyses substantially different from those already carried out in conformance with NEPA requirements. It should be noted that those parts of the proposed standards which impose significant new requirements have been phased in time so as to permit orderly regulatory implementation with adequate lead times for their integration into plant design and construction schedules.

In addition to the NRC regulation discussed above, certain facilities in the uranium fuel cycle (some mills and conversion plants) are now regulated by States under agreements with the NRC. This is also not expected to result in any implementation difficulty, since such "Agreement States" must, under terms of the authorizing statute for these agreements, conform to NRC regulations, which in turn must implement EPA standards.

ERDA is directly affected through requirements of these standards at its uranium enrichment facilities. No substantial impact is anticipated, however, since these facilities now operate well within the proposed standard, according to published AEC data. In addition, further investigations of control systems for krypton-85 and iodine-129 (as well as other effluents) are being carried out by ERDA at various national laboratories as a continuation and expansion of activities previously underway under the auspices of AEC. The requirements set forth by these standards underscore the need for these activities, and the wisdom of their pursuit in the past.

It is anticipated that any desirable modifications of procedures and regulations for transport of radioactive materials associated with operations of the fuel cycle (especially spent fuel and high-level waste shipments) will be carried out jointly by NRC and DOT, which share the responsibility for insuring adherence to radiation protection guidance in this area. Such modifications are anticipated to consist principally of measures to insure that such materials do not remain for substantial periods of time at locations where members of the public may accumulate substantial doses.

The standards should also facilitate the preparation and review of environmental statements for individual facilities by providing a clear statement of environmental radiation requirements from the agency responsible for determining these requirements. They are not anticipated to incur substantial additional analysis, due to their applicability to the total dose from all facilities in any particular region, because such impacts are, in general, extremely small in comparison to the proposed standards.

E. INTERMEDIA EFFECTS

The proposed standards encompass pollutants discharged via both air and water pathways. They also imply commitments of land use for the storage of both the high and low level wastes collected by control systems. In general, choice of the release pathway that involves the minimum environmental impact is unambiguous; the only major exception is for release of tritium. And in general, the waste disposal implications of the standards are most serious for long-lived radioactive wastes. However, the incremental amounts of these wastes are very small for the controls required by these standards, compared to the already-existing quantities produced by nuclear power facilities, i.e., those that do not result from effluent control choices.

There is no presently available control mechanism for tritium; the possibility of future control at fuel reprocessing facilities (the principal source of tritium releases) has been discussed in a number of investigations (46). For the present, the alternatives available for reducing population exposure are limited to dispersal via air-versus-water. A portion of the population dose delivered when tritium is dispered to air occurs over the long term and on a worldwide basis. This worldwide portion of the dose is the same when tritium is dispersed via water. The balance of the dose is delivered promptly to the U.S. population, and, if delivered via air, is relatively independent of the characteristics of the effluent site and approximately three times larger than the worldwide population dose. If delivered via water, the population dose is extremely site dependent, ranging from negligible to approximately ten times larger than the worldwide component of population dose. The important variable is whether or not the receiving waters are used for public drinking water supplies. An additional complication is the possibility of additional contamination by other radionuclides if water is the dispersal route. Although the proposed standards do not address the issue of the most expeditious choice of release pathway for tritium, it is recommended that the discharge pathway delivering minimum dose be determined by the regulatory agency and required on a site-by-site basis.

Disposal of radioactive effluents through dilution and dispersal in air or water has, in the past, been a common method for satisfying radiation protection requirements, which have been commonly expressed as maximum permissible concentrations in air and water. The alternative is that contemplated by these standards: collection of these materials through the use of effluent control systems at the source followed by storage of long-lived materials using one of several long-term waste management schemes. The environmental question is which alternative, over the long term, presents the least environmental hazard. The answer in the case of materials having half-lives less than about 100 years is unequivocally in favor of storage, since this route reduces the probability of future human exposure to a small value. In the case of longer-lived materials storage is also the preferred route. However, the possibility exists that future releases of stored materials may take place, with attendant human exposure, and the magnitude of this possibility is not well-defined. These waste management issues are not addressed by this rulemaking. It is simply assumed that waste management represents an improvement over disposal, with high probability of success in the short term, and with reasonable prospects for success over the long term. Although this issue is basic to the environmental viability of nuclear power, it has been treated as separable from the question of reasonable levels of planned effluents because the wastes generated by effluent control systems represent only a small addition to the total waste management problems of the industry.

The issues associated with the decommissioning of facilities are ultimately again those of waste management. The incremental problems to decommissioning represented by a few additional effluent control systems are a small perturbation on the already-existing burden for decommissioning of these facilties as a whole.

F. IMPACT ON FACILITY DISTRIBUTION AND REACTOR MIX

We discuss four related matters below. These are the potential impact of the proposed standards on: 1) the location of a number of reactor units on a single site, 2) the number of sites in a given geographical area, 3) nuclear energy centers, and 4) the mix between nuclear and fossil fueled electrical energy production. It is concluded that the proposed standards will have little, if any, impact on any of these.

1. Multiple Reactor Units on Single Sites

The number of reactors at a given site could be limited, at least in principle, by an ambient environmental radiation standard applying to all activities in the uranium fuel cycle (47,48). In order to examine this possibility, conclusions developed during the AEC's (now NRC) rulemaking on as low "as practicable" (ALAP) reactor effluents, AEC and NRC dosimetric estimates for real sites in environmental statements, the results of EPA field studies, operating data for reactors, and some analyses of hypothetical configurations are each examined in turn below. First, however, we digress for a brief assessment of the number and sizes of multiple reactor sites to be expected, based on actual commitments by utilities during the next decade.

a. Multiple reactor site projections

Originally, nuclear power reactors were constructed as individual units, each on its own site. As nuclear power became more attractive economically and technologically, multiple reactors were ordered for single sites. A recent listing of all reactors in operation, under construction, or on order (49) reveals that there are only five sites for which as many as four reactor units are presently committed. TVA also has plans for four more reactor units at as yet unspecified locations, which may or may not be built on the same site, but since these units have not even been located yet, it will be at least eight years before they can begin operation. These four-unit sites are:

Site	Location	Commercial Operation Expected for Last Unit
Alan R. Barton	Verbena, Ala.	1987
Hartsville	Hartsville, Tenn.	1982
North Anna	Mineral, Va.	1981
Shearon Harris	Newhill, N.C.	1990
Surry	Gravel Neck, Va.	1984

Thus, it is likely to be at least five years before any four-unit site could be in operation. No sites containing more than four reactor units are presently committed. Considering the lead time of eight years necessary (from contract award to commercial operation) for a single reactor unit, it will apparently be at least a decade before any five- or six-unit site could become operational.

b. Considerations from the ALAP rulemaking

One of the basic questions considered by the NRC in the rulemaking for as low "as practicable" discharges from light-water-cooled nuclear power reactor effluents was whether the design objectives of Appendix I to 10 CFR 50 should apply to each reactor or each site.

The original proposal would have applied the basic dose limits to entire sites. However, in the words of the Commission (50):

> We have chosen to express the design objectives on a per light-water-cooled nuclear power reactor basis rather than on a site basis, as was originally proposed. While no site limits are being adopted, it is expected that the dose commitment from multi light-water-cooled reactor sites should be less than the product of the number of reactors proposed for a site and the per-reactor design-objective guides because there are economies of scale due to the use of common radwaste systems for multi-reactor sites which are capable of reducing exposures.

Later, in a more detailed discussion of this question (50), the Commission expressed the view:

> We are also of the opinion that it will be at least several years before sites containing as many as five light-water-cooled nuclear power plants are developed. Consequently, we see no way that design-objective guides set on a per-reactor basis can, in the near future, result in individual exposures that are more than 5% of present-day (10 CFR 20) radiation standards. Indeed, we believe that, with the required inclusion of all radwaste augments justified on a cost-benefit basis and with the realization that several reactors cannot physically be placed so as to all be a minimum distance from the maximally exposed individual, the actual doses received by individuals will be appreciably less than this small percentage.

Thus, it was the opinion of the Commission that the radiation doses from multi-reactor sites, containing up to five light-water-cooled nuclear power reactors, will remain at small percentages of present-day (10 CFR 20) radiation standards, specifically, at less than 25 mrem/yr to the whole body and 75 mrem/yr to the thyroid.

c. Results of NEPA reviews

For the last few years, the AEC and NRC have filed environmental statements under the provisions of the National Environmental Policy Act; these environmental statements assess the expected performance characteristics for projected nuclear facilities, including nuclear power reactors. Table 11 summarizes the results of these analyses for radioactive releases from all sites projected to contain three or more reactors. The table shows that:

1. For the eleven such sites analyzed, in only one case is a whole body dose by any pathway greater than 2 mrem/yr projected. The exception, 12 mrem/yr to a hypothetical individual consuming 18 kilograms per year of shellfish collected from the reactor discharge canal, is based upon the assumption that public access to that canal is permitted.

2. For no site is a maximum dose of more than about 15 mrem/yr to the thyroid of an infant at the nearest farm necessary if reasonable and readily available control measures are instituted.

It must be emphasized that the estimated doses in Table 11 have been calculated using conservative models. Even though the most recent environmental statements employ models specified by regulatory guides which are more realistic than those used in the past, these models are still conservative. Again, in the opinion of the Nuclear Regulatory Commission on Appendix I to 10CFR50 (50):

TABLE 11

ENVIRONMENTAL IMPACTS OF THREE- AND FOUR-UNIT SITES

		Dose Equivalent Rate (mrem/yr)			
		Whole Body			Thyroid(a)
Site	EIS (Date)(b)	Gaseous	Liquid	Site Gamma(c)	Iodine
Four-Unit Sites					
Hartsville	6/75	<1	<1	<1	16(d)
Alan R. Barton	4/75	<1	1.3	<1	2.2
WPPSS (Hanford)(e)	3/75	1.2	2.5	<1	9
Surry	6/72,5/74	<1	2.5	<1	49(f)
Shearon Harris	3/74	<1	12(g)	<1	15(h)
Vogtle	3/74	<1	<1	<1	4
North Anna	4/73	<1	1.3	<1	4.9
Three-Unit Sites					
Davis-Besse	2/75	<1	2.2	<1	1.8
Pilgrim	6/74	1.3	<1	<1	2.9
Millstone	2/74	<1	<1	<1	10
Dresden	11/73	<1(i)	<1	<1	7
Indian Pt.	10/73	2.4	<1	<1	<1
San Onofre	3/73	<1	<1	<1	<1
Browns Ferry	9/72	2	<1	<1	<1
Oconee	3/72	1	<1	NR	5

(a) Dose equivalent to infant thyroid via cow-milk-pathway at nearest farm.

(b) All are final environmental statements except Barton, Davis-Besse, and Pilgrim, which are draft statements.

(c) 500 hours unshielded occupancy of boundary per year.

(d) The applicant's facility design, as proposed, would result in a dose of 74 mrem/yr, which was not deemed "as low as practicable" by the NRC staff. Addition of a turbine building ventilation treatment system could reduce the total dose to about 16 mrem/yr, as indicated in the statement.

(e) Does not include dose equivalents from the Hanford N-Reactor, which is a light-water-cooled, graphite moderated reactor.

(f) 98% of the release is from the condenser air ejector and steam generator blowdown tank vent pathways of Units 1 and 2 and can be eliminated or drastically reduced through simple modifications of existing control equipment.

(g) Assumes public access to cooling water discharge canal and annual consumption of 18 kg of fish and mollusks raised in discharge.

(h) Monitoring and appropriate operational practices will be required by NRC to assure that dose levels do not exceed 15 mrem/yr; NRC considers the calculated dose without such measures (28 mrem/yr) very conservative (i.e., the actual dose will be lower.

(i) Based on augmented system committed by applicant (p.11-40 of EIS).

NR - Not Reported.

> It must be understood in discussing the matters of calculational conservatism and realism that Appendix I means, implicitly, that any facility that conforms to the numerical and other conditions thereof is acceptable without further question with respect to section 50.34a...The numerical guidelines are, in this sense, a conservative set of requirements and are indeed based upon conservative evaluations.

In any event, the results presented in Table 11 indicate that for all multi-reactor sites for which environmental assessments are available, the maximum projected dose is less than 5 mrem to the whole body, even under the highly unlikely presumption that the maximum whole body doses for gaseous and liquid effluents add arithmetically. Thyroid doses would limit the number of such reactors at a given site to no greater extent than do whole body doses. This conclusion is, of course, in harmony with that reached by the NRC that sites containing as many as five light-water-cooled nuclear power reactors would result in individual exposures that are appreciably less than 25 mrem/yr to the whole body and 75 mrem/yr to the thyroid.

d. Results from field studies

In addition to the estimates of dosimetric impact made using "realistically conservative" calculational models, the EPA and its predecessor organizations have conducted detailed surveillance programs at selected facilities (33,34,51,52). These studies have confirmed the accuracy of reported effluents of noble gases and liquids, but appear to reveal significantly lower iodine concentrations in milk than projected by models for the milk pathway currently used for environmental analysis.

Field studies conducted by the EPA at Dresden (Unit 1), Yankee Rowe, and Haddam Neck (formerly Connecticut Yankee) have shown the following maximum individual doses to the various organs listed (33,51,52):

Maximum Individual Dose (mrem/yr)

Organ	Dresden	Yankee	Haddam Neck
Whole body	8.0	3.0	3.8
Thyroid	0.74	0.006	6.0
Bone	0.026	0.20	3.0
GI (LLI)	0.008	0.26	0.4

It should be noted that these values are absolute maximum doses for each organ; all pathways possibly contributing dose to a particular organ were summed to arrive at the above totals. These doses thus presume that an individual could be simultaneously exposed to all pathways of exposure and that he would receive the maximum possible dose from each pathway. Thus, these doses are extremely unlikely to have been received by any real individuals, as was pointed out by the authors of the Dresden and Yankee studies (34):

> ...a farmer near Dresden may eat beef, green vegetables, and drink milk, but he would not also eat 100 gms of fish per day that had been caught at Starved Rock Dam, neither would he consume Peoria drinking water, nor does he reside in the areas for which inhalation and external whole-body exposures were calculated. Consequently, actual radiation exposures to existing populations in the vicinity of both nuclear power plants are less than the total dose rates listed....

Furthermore, most of the whole body dose listed for the pressurized water reactors (PWRs), Yankee Rowe and Haddam Neck, result from direct radiation originating from stored radioactive waste (gaseous and liquid storage tanks). This exposure may be minimized by simple shielding or careful placement of these tanks relative to the site boundary. Virtually all of the thyroid dose and bone dose at Haddam Neck results from the hypothetical consumption of fish (18 kilograms per year) caught in the discharge canal. Almost all of the whole body dose listed for Dresden results from exposure to the gaseous effluent (principally noble gases) discharged from the stack; boiling water reactors (BWRs) such as Dresden are presently augmenting (or have already augmented) their noble gas treatment systems to provide additional dose reduction factors of 8 to 180 beyond those in force at the time the above studies were carried out (48). The three reactors studied are also of early design. Reactors going into operation today or in design and construction stages incorporate considerably more sophisticated radwaste treatment systems having larger processing capacities, greater cleanup efficiency, and increased flexibility.

Doses due to gamma radiation (directed and scattered, or "shine") originating onsite can be significant at BWR sites because of the circulation of activation-produced nitrogen-16 through the turbines and associated equipment, particularly the moisture separators. The EPA field studies discussed above considered the whole body dose from direct gamma radiation only for the PWR field studies (Yankee Rowe and Haddam Neck). Subsequent field measurements made by the EPA, ERDA, NRC, and others have shown that dose rates on the order of 10 mrem/yr (whole body) at 500 meters are possible without supplementary shielding of turbine building components; these dose rates, however, decrease very rapidly with distance so as to produce very small population doses (53-56). In addition, dose rates are very dependent upon the design and layout of the turbine and its associated equipment. Appropriate design of shielding and location of turbine components relative to the site boundary can assure that offsite doses from "turbine shine" are minimized. The siting of many reactor units at a single site should also result in significantly smaller offsite doses from turbine "shine," as the exclusion distance increases with the number of reactor units on a site. According to a recent study (57), the exclusion distance averaged 460 meters for single unit BWRs and 860 meters for twin-unit BWR sites; for PWRs, single units sites averaged 750 meters, while twin-unit sites averaged 900 meters. Since the dose from turbine "shine" falls off very rapidly with distance, such doses should be significantly reduced for multi-reactor sites. For example, using the data from the most recent study (56), the dose rate falls off by a factor of five as the distance increases from 460 meters to 860 meters. Therefore, it is to be expected that dose rates from turbine "shine" at multi-reactor sites will not be significant compared to those from the single unit sites at which field studies have taken place.

Studies of iodine pathways and potential thyroid doses have been conducted jointly by EPA and AEC over the past two years at the Dresden, Monticello, Oyster Creek, and Quad Cities sites (34). The available results present a consistent picture of iodine concentrations in milk less than these projected by models for the milk pathway currently used for environmental analyses.

e. Results from reactor operation

In addition to conservative environmental dose pathway models, radionuclide source term models have also been conservative. For example, fuel experience for PWRs has been much better than the 0.25% fuel leakage rate now used as a design basis for calculating environmental releases. Westinghouse, which has manufactured the great majority of operating PWRs, reports that fuel integrity has generally been in the neighborhood of 99.98% (i.e., a fuel leakage rate of 0.02%) for zircaloy-clad fuel. Exceptions to this high level of fuel integrity occurred in 1969-1970, when hydriding lowered fuel integrity to the 99.8-99.9% range, and in 1972, when fuel densification lowered fuel integrity to the 99.9% range (58). On the other hand, BWRs which have typically been designed for fuel leakage corresponding to the release of

100,000 μCi/sec of noble gases from the air ejector, after a nominal 30 minute delay, exhibit a more variable performance. Figure 5 shows that this design value had yet to be reached by BWRs operating through 1973; indeed, most were very much below the design value (32). Recent data, however, indicate a rising trend of releases from BWRs, and EPA is maintaining a continuing surveillance of this trend, which may indicate that the present design basis is too low to provide adequate assurance that Appendix I design objectives will be satisfied in actual operation. In general, however, fuel integrity at PWRs and for pre-1974 BWR performance has been considerably better than predicted by conventional source term models used in environmental analyses.

A second important consideration with respect to conservatism in source term models is the fact that, especially for PWRs, effluents are postulated for inplant pathways which require simultaneous levels of degradation of several parameters in order to lead to a postulated release to the environment. For example, effluents from the PWR secondary system (e.g., steam generator blowdown vent or condenser air-ejector exhaust) require the simultaneous existence of a "design basis" assumed fuel leakage and a "design basis" assumed steam generator leakage rate of primary coolant into the secondary coolant. Since the probability of each "standard" assumption is generally significantly less than one, the probability of both occurring at the same time must be smaller than either of the individual probabilities. Thus, if the annual probability of having the "design basis" number of fuel failures is five percent and the probability of having a "design basis" primary to secondary leak is twenty percent, the probability of operating a PWR with "design basis" fuel leakage and primary to secondary leakage is of the order of one percent. In spite of this, light-water-cooled reactors have been evaluated as if these "design basis" conditions occur simultaneously, for periods of time comparable to a year (59).

f. Analysis of the additivity of doses from multiple facilities

Similar considerations apply to the assessment of doses from multiple facilities on a single site. A variety of site specific factors exist, including the site size, the relative location of individual facilities on the site, and economies available through utilization of design incorporating shared control measures, each of which mitigate against arithmetic additivity of doses to a maximum exposed individual outside the site boundary. In general, these effects are quite significant, as is reflected by the low doses projected for those sites which have been subjected to analysis, as, for example, in the environmental statements quoted above. Indeed, these sites project lower doses than many single unit sites. In addition, however, there is significant operational flexibility available at a multi-unit site not available to sites containing single or double units. For example, if a reactor at a four-unit site is experiencing a severe rate of fuel failure, the output of the site could be maintained at a respectable 75%

of capacity while that reactor is serviced, by operating the remaining units at full fuel capacity, a degree of flexibility not available to a one- or two-unit site without calling upon another portion of the power grid to take up the loss of capacity.

In addition to the above considerations, which in actual situations should generally be overriding, it is, however, also necessary to consider the question, "to what degree are doses from identical reactors located on a site additive?" It is instructive to consider the following hypothetical example. Assume that all units on a site are located at exactly the same point, and that each is designed to no more than conform exactly, using "design basis" assumptions, to the design objective doses specified by Appendix I (say, 5 mrem whole body dose via the air pathway) to some common hypothetical worst case receptor. Assume further, since under Appendix I this dose is to be exceeded only in "temporary" and "unusual" situations (50), that one may assign some reasonable probability that, on an annual basis, the design objective dose for any single unit will not, in fact, be exceeded. For example, the 0.25% fuel failure assumption currently used as a design basis for PWRs is not exceeded, on the basis of current operating history, at least 95% of the time. What then, is the dose that can be expected to be not exceeded at the same confidence level (95%) for 4, 5, or 6 such units? That the answer is not 4, 5, or 6 times 5 mrem/yr is obvious. The exact result is dependent upon the variance of the operating data, and, to a much lesser degree, the shape of the distribution of the data. A statistical analysis utilizing actual operating data for PWRs and BWRs yields the following projections (60):

Dose Levels (mrem/yr) that will be Satisfied 95% of the Time*

	4 Units	5 Units	6 Units
PWR	14	17	20
BWR	15	18	21

*For single units which each satisfy Appendix I at the 95% confidence level.

Each of these values is significantly lower than that predicted by an assumption of additivity, even for the extreme case of colocation of all units, no exercise of operational flexibility, and design for the maximum release permitted by Appendix I considered here.

On the basis of: a) results projected by the AEC and NRC for all multi-unit sites presently committed, b) the flexibility available through proper selection and utilization of future sites, c) the conservative nature of design dose calculations, as opposed to the applicability of these standards to exposures actually received, d) the nonadditivity of design basis dose contributions from single units, and e) the operational flexibility available to sites with multiple units, it is concluded that the proposed standards can be readily achieved at all presently planned and all properly designed future multi-unit sites of up to at least six units. It is further noted that in "unusual" circumstances during which the design objectives specified for light-water-cooled reactors by Appendix I may be "temporarily" exceeded (50), that the variance provision of the proposed standards would permit continued operation in times of necessity. Questions associated with even larger configurations of units, such as nuclear energy centers, are addressed separately below.

2. Multiple Sites

Uranium fuel cycle facilities in a particular geographical area could also consist of a large number of plants (of the same or mixed types) on multiple sites in the same general area so that the potential for overlapping doses to members of the general public exists. The Agency has investigated the likelihood of such overlapping doses from multiple sites (Section V-D). The potential for the proposed standards to be exceeded (or more precisely to require significantly increased control in order to be met) by overlapping doses from multiple sites was found to be very small because of the very special physical siting conditions that would have to exist. Such situations are not expected to occur with any significant frequency nor with any significant impact.

3. Nuclear Energy Centers

A somewhat similar question arises in connection with the proposed nuclear park concept (61). The Federal Register notice proposing these environmental radiation standards for the uranium fuel cycle pointed out that "...in view of the need to accumulate operating experience for the new large individual facilities now under construction and the intent of the Agency to review these standards at reasonable intervals in the future, it is considered premature and unnecessary to predicate the standards on any siting configurations (e.g., nuclear energy centers) postulated for the next decade and beyond. The Agency will consider changes in these standards based on such considerations when they are needed and justified by experience..." (47). The proposed standard does not itself specify standards for any specific siting configuration, nor is any siting concept excluded from its applicability. EPA's commitment is simply to reconsider the standard when data is available on which to base an evaluation of the nuclear energy center (NEC) concept.

A number of commenters on the Draft Environmental Statement addressed the NEC concept in somewhat general terms. They expressed two types of concerns. The first was expressed by one commenter as follows: "...however, the proposed limits may discourage plans for energy parks for the following decades. Since the (sic) energy parks may well offer reduced overall radiation and health effects to the general public (at the expense of slightly higher individual exposures) along with possible cost savings and safeguards improvements, the long range implications of the standards on the parks should be explicitly addressed..." (62). The second concern seen is: "By specifically excluding nuclear parks from the standards, EPA makes utility planning for the design, purchase and construction of future nuclear power plants difficult" (63). None of the commenters provide any quantitative information to support their concerns.

Three in-depth studies of nuclear energy centers have been published. One, titled "Assessment of Energy Parks vs. Dispersed Electric Power Generating Facilities," and sponsored by the National Science Foundation (64), did not treat radioactive effluents in enough detail to indicate whether the proposed standards would or could be met. That study referenced "Evaluation of Nuclear Energy Centers" (WASH-1288) on this matter (65).

WASH-1288 provides the most complete treatment of NEC's available prior to the more detailed studies of the Nuclear Energy Center Site Survey recently completed by NRC, and evaluates two real sites in enough detail to draw some conclusions. Appendix 1 of WASH-1288 provides a discussion of the Hanford reservation in Richland, Washington as a potential site, which includes an evaluation of potential radioactive effluents. The results indicate that 25 reactors and a reprocessing plant could be sited at Hanford with a radiological impact which should be significantly less than permitted by the proposed standards (66).

Appendix 2 of WASH-1288 provides a similar treatment of a site at River Bend, Louisiana, and also estimates an impact less than that permitted by the proposed standards (67). It should be noted that

WASH-1288 was written in 1973, and the authors were concerned with meeting the then proposed Appendix I. Thus, effluent controls are assumed in the discussions that will achieve calculated doses in accordance with proposed Appendix I.

Appendix 5 of WASH-1288, "Radiological Impact of a Nuclear Center on the Environment" contains a generic treatment of radioactive effluents by Soldat. Based on his evaluation, it appears that the proposed standards for atmospheric releases would be met if prudent site selection is made and reasonable levels of effluent control provided.

One potential problem indicated by Soldat that would require special attention is liquid releases. If radionuclides are released from a large number of reactors into a single body of water, special radioactive waste processing systems or operating procedures may be necessary, such as onsite receiving ponds. This would depend on the specific characteristics of the water body for receiving possibly large quantities of radionuclides (68).

WASH-1288 does not answer all of the concerns expressed by commenters on the proposed standards. The analyses are of a scoping nature and do not address the advantages and disadvantages of NEC's versus dispersed siting, nor in any detail the impact of other considerations (thermal and potential accidents, for example), which would certainly be appropriate to any decision on standards specifically designed for NEC's.

The "Nuclear Energy Center Site Survey" (6) prepared by NRC was issued in January 1976. The survey treated two radiological aspects of reactor only Nuclear Energy Centers: 1) the effect of arrangement of reactors on the offsite dose commitment, and 2) the radiological environmental impact from an hypothetical nuclear energy center (based on currently used effluent control technology). The results of the NECSS analysis show that the arrangement does not greatly infuence dose commitments as long as there is some distance from the nearest reactor (or group) to the site boundary. With regard to dose commitments it was concluded that the dose commitment from a NEC would essentially meet the Appendix I objectives for a single reactor. The exception was child thyroid dose which was calculated to be 112 mrem/yr for the 40 unit site. The calculation included the milk pathway (111 mrem) with a "fencepost cow" grazing the entire year. It would be expected that an actual NEC with 10-20 reactors as recommended by the NRC, and calculations based on more realistic pathways, would result in a childs thyroid dose of less than the 75 mrem proposed by EPA.

For NEC's also containing other fuel cycle facilities, in various combinations, there are situations where the calculated doses exceed the EPA standard. However, in those cases either 1) the proposed standard would not apply (such as Pu recycle), 2) the case is extreme

(9000 MTHM reprocessing capability on one site), 3) the effluent control technology assumed is not what would be expected under the EPA standard, and 4) measures would be available, as is clearly pointed out in the report, that could significantly reduce the doses. Thus, an examination of the NECSS does not reveal any significant conflicts between the proposed standards for the uranium fuel cycle and the feasibility of the NEC concept. Such a preliminary finding does not, of course, preclude a later finding, based on a more detailed study, that some specific provisions may be required in the standards for such sites.

The task of completely assessing the potential impact of the proposed standards on NEC's is beyond the scope of this discussion. However, some of the unique aspects of NEC's that are involved can be briefly mentioned.

There are some characteristics of NEC's that will make doses to members of the public less than might be expected on the basis of assessments for conventional sites. The exclusion distance or the distance to the nearest boundary from such a large group of plants can be expected to be greater than for smaller numbers of facilities on conventional sites. A distance of one to one and one half miles may be typical versus the typical one half or less miles for conventional sites. The sites for NEC's are likely to be quite large (50-75 square miles) with the plants dispersed over the site in order to minimize effects from thermal releases to the atmosphere. NEC sites may also be relatively remote. Economies of scale and shared systems may also make some effluent control systems available that would not be cost-effective at conventional sites.

The dose at the site boundary will not be the multiple of the number of reactors times the dose from the nearest reactor to the site boundary. Soldat (69) has calculated that the increase in dose over that due to the nearest facility (or group) would be a factor of from two to five. A scoping calculation carried out by EPA for thyroid doses arrives at a factor of three. Of course this would vary depending on actual site factors and could increase with the addition of other fuel cycle facilities, such as fuel reprocessing. However, one would expect that such other fuel cycle facilities would be placed well away from the boundary of the large sites required for NEC's and not contribute a disproportionate part of the total dose.

Before definitive conclusions can be drawn, all pathways will have to be considered on a consistent basis; the sensitivity of doses to a variety of site factors will require evaluation; the effect of adding fuel cycle facilities must be quantified; quantification of the potential population dose reduction and related benefits achieved by such sites in relation to any increased maximum individual dose will be necessary; and any benefits that could be achieved through shared effluent control systems will have to be evaluated.

Based on the information now available, the lack of any other quantitative input from any source to the contrary, and the expectation of prudent and sound siting decisions, it appears likely that nuclear energy centers will meet the proposed standards. However, should specific proposals for nuclear energy centers be pursued in the future, EPA will review the entire spectrum of analyses of expected impacts and benefits provided by future more detailed assessments of proposed specific sites, and by experience in the immediate future with existing facilities, in order to arrive at a judgment on the appropriateness of these environmental radiation standards for nuclear power to such possible future siting configurations.

4. Reactor Mix

The proposed standard was also examined with respect to the possibility that it might influence the mix between the use of nuclear and non-nuclear fuels for the production of electrical power. The ease with which the proposed standards can be met, both technically and economically, leads to the ready conclusion that these standards could not have any such influence.

VII. ALTERNATIVES TO THE PROPOSED ACTION

In the course of developing these proposed standards, the Agency has considered a variety of alternative courses of action. These fall into two broad categories. The first encompasses what may be characterized as administrative alternatives, and includes modification of existing Federal Radiation Protection Guidance for Federal agencies, issuance of generally applicable environmental standards for the fuel cycle as a whole (the recommended course of action) or for specific classes of activities within the fuel cycle separately, and, finally, the alternative of no standards. The second category encompasses different levels of generally applicable environmental standards for the entire fuel cycle, and includes standards with and without variances for abnormal situations and at various levels of cost-effectiveness of risk reduction, including the extreme case of applying best available technology, without regard to the degree of risk reduction obtained. Each of these alternatives are discussed below, beginning with those characterized above as administrative.

Existing Federal Radiation Protection Guides for annual radiation exposure of members of the general public apply independently of the source of exposure. These general guides could have been revised downward, or a portion of the existing guides could have been apportioned to the nuclear power industry as representing an acceptable level of health risk for the benefit of receiving electrical power. The development of such revised or apportioned general guides need not depend upon a detailed analysis of the capabilities of effluent control technology, since only a judgment of what level of exposure will result in either a negligible or an acceptable level of health effects is required. Such a judgment requires either a) the demonstrated existence of a threshold for all significant radiation effects (which can be attained by the industry), or b) public acceptance of some level of dose as representing a "negligible" or "acceptable" risk. However, the recent NAS-NRC review of somatic and genetic effects of radiation again rejected use of a threshold assumption for setting radiation standards, and there is neither a publicly accepted level of negligible or acceptable risk, nor any realistic prospect for obtaining agreement on a value for such a general concept. Finally, when considering the risk to public health of nuclear power in relation to its benefit, it is clearly not acceptable to permit a health risk equal to that benefit; what is required is to maximize the residual benefit by minimizing the associated risk to health. However, since they cannot reflect the detailed control capabilities of different kinds of sources, guides based on health alone cannot minimize annual environmental radiation exposures; they can only provide a ceiling on the permissible level of pollution. Also, it is not clear how to modify or apportion existing guides so as to prevent environmental buildup of long-lived materials. The Agency concluded that this alternative could not provide adequate environmental protection.

The fuel reprocessing industry represents the largest single potential source of radioactive effluents from the uranium fuel cycle. The Agency could have proposed effluent standards based on cost-effective risk reduction for this portion of the industry alone, as a first step, and issued standards for other components of the fuel cycle subsequently. Such a course would provide for satisfactory protection of the environment, especially from long-lived radioactive effluents, and it would involve a much shorter initial analysis than is required to set comprehensive radiation protection standards for the entire fuel cycle. However, such standards a) would not be nearly as responsive to legitimate public concerns about radiation from the industry as are comprehensive standards, and b) could infringe upon the licensing responsibilities of the NRC for individual facilities. Finally, adoption of this alternative would represent an inefficient use of governmental resources. As many as six separate rulemakings eventually would be required to complete the establishment of comprehensive standards for the industry. This alternative was not adopted because it is inefficient, is in potential conflict with a reasonable division of EPA's responsibilities for environmental standards-setting and NRC's regulation of specific facilities, and would not adequately respond to public concerns about the environmental implications of planned radioactive releases from nuclear power.

EPA could also choose to issue no standards and instead exert its influence to reduce environmental releases by publishing technical analyses of the environmental impact and control capabilities of the various components of the fuel cycle. This alternative would require the least immediate effort and would not result in the possibility of substantial environmental degradation during the next few years. However, the need to establish needed precedents for control of environmental radiation from nuclear power through issuance of formal Federal standards for protection against environmental degradation by long-lived radioactive materials would not be exercised, and facilities now in the design stage would be faced with the need for costly potential retrofits in later years. Of even greater importance, the Agency would be failing to carry out its basic responsibility under Reorganization Plan No. 3 to set environmental radiation standards to insure adequate protection of public health.

In summary, the environmental inadequacies of a revised Federal guide for individual exposure, the need for definitive EPA standards to control the environmental implications of the entire nuclear power industry, and the efficient use of Agency resources argue conclusively for the administrative alternative adopted. This alternative permits a balanced consideration of the reduction of deleterious health effects which takes into account the costs and capabilities of controls, and which limits the quantity of long-lived radioactive materials released by the industry so as to minimize irreversible environmental contamination. It thus best satisfies all environmental concerns and is at the same time most responsive to the Nation's energy priorities.

The Agency has, in addition, considered three major quantitative alternatives to the proposed action. The first alternative incorporates standards with higher limits on individual dose that would apply to any operating situation (i.e., not just to normal operations) and utilizes annual population dose rather than quantity of long-lived radionuclides per gigawatt-year as the unit of measure for standards to limit the accumulation of these radionuclides in the environment. It is substantially the alternative proposed by the AEC in their memorandum to the President (October 19, 1973) concerning the division of responsibilities between AEC and EPA (70), and for which numerical values were advanced in subsequent discussions between the two agencies. The second alternative is similar to that proposed, but is somewhat more restrictive. It represents the lowest levels that can be justified on the basis of reasonable levels of cost-effectiveness of risk reduction, and requires the implementation of restrictions on the release of long-lived radionuclides on a shorter timetable than that proposed. The final alternative considered is for substantially lower limits on both individual dose and quantities of long-lived radionuclides in the environment than those proposed by this rulemaking action. These limits represent the lowest ambient environmental levels achievable by the fuel cycle using the most effective technology available for effluent control, regardless of the associated costs. The types of control technology required to achieve the levels contemplated by each of these alternatives are limited to those either currently available and used by NRC licensees or those in advanced stages of development, in which case sufficient lead time is provided by the alternative standards for any further development and safety evaluation required prior to their use by licensees. Detailed analyses of control costs and the associated levels of environmental and public health impacts of these various levels of control are provided in references 7-10 and 71.

Alternative A: Replace the entire proposed Subpart B by:

> a) The annual dose equivalent to a member of the public from radiation or radioactive materials released to the environment from the entire uranium fuel cycle shall not exceed 50 millirems to the whole body, 150 millirems to the thyroid, and 150 millirems to any other organ; and b) the total annual population whole body dose from radiation or radioactive materials released to the environment from the entire uranium fuel cycle shall not exceed 1 man-rem per megawatt of electric capacity.

The first part of this alternative provides considerably higher upper limits of dose than those provided by the proposed action for normal operations and, unlike the standards in the proposed action, these are intended to be interpreted as shutdown values beyond which any fuel cycle facility causing the standard to be exceeded would be required to suspend operations. For this reason no variance is provided. Justification of this limit must therefore result not from a determination of what constitutes an acceptable level of normal operation with respect to environmental impact, but rather from a determination of an unacceptable level of population risk, or an unsafe level of operation. Such a determination is not possible, in general, because knowledge of the particular conditions associated with each case of potential or actual operation above such a limit is required. Nor is it clear, with respect to safety, that EPA rather than NRC bears the primary responsibility for such a determination.

The environmental benefit to be derived from establishment of standards at these levels would be negligible, since the potential for actual operation of any facilities above such limits is already vanishingly small. There appears to be no known instance of a reactor having ever delivered such doses to any actual individual in the general environment, even with the relatively unsophisticated levels of effluent control in effect over a decade ago (72).

With respect to the second part of this alternative, the current annual population whole body dose to the world's population is approximately 0.13 man-rems per megawatt of electric power produced, or approximately 0.1 man-rems per megawatt of capacity, at present actual operating levels of U.S. fuel cycle facilities. These values are achieved without any limitation on environmental releases of long-lived radionuclides, such as krypton-85 or tritium. Thus, a standard of 1 man-rem per MW(e) would have no impact whatsoever on either population exposures due to short-lived radionuclides or on local or worldwide environmental buildup of long-lived radionuclides.

If this alternative were modified so as to apply to the environmental dose commitment, rather than to the annual population dose, the value proposed would still have absolutely no effect on releases of long-lived materials, since the environmental dose commitment per GW(e) of capacity, assuming release of all tritium and krypton, is currently approximately 0.3 man-rems. (The above assessments do not include the impact of carbon-14, since the limits proposed also did not.)

The economic costs associated with this alternative are only slightly smaller than those for the proposed standard. It is assumed that Appendix I would still continue to be implemented for control of normal releases, since the standards for individual exposure apply to abnormal, not normal, releases under this alternative. Some cost saving would result from the absence of any requirement to control releases of long-lived radionuclides; this is estimated to amount to approximately 0.7 million dollars per gigawatt of fuel cycle capacity. An additional reduction of capital cost of up 0.3 million dollars per gigawatt of fuel cycle capacity could result under this alternative from failure to upgrade fuel supply facilities to "as low as practicable" levels of control similar to those required at reactors by Appendix I. These savings would amount to approximately one-tenth of one percent of the capital cost of a unit of power supply capacity.

The principal environmental and health impacts of this alternative would be that environmental burdens of the long-lived radionuclides krypton-85 and iodine-129 would be increased by one or two orders of magnitude and an increase of approximately 1000 health effects (attributable to releases over the next 25 years) over that associated with the proposed standards due to lack of control of these long-lived radionuclides would occur. The administrative impact would be decreased by lack of a requirement to develop controls for these materials, and increased by failure to provide standards to assist the development of design and operating guidance and to facilitate the preparation of environmental statements for facilities in the fuel cycle other than reactors.

This alternative is environmentally and administratively unacceptable: it would provide negligible environmental benefit, would encourage rather than restrict the continued accumulation of irreversible environmental burdens of long-lived radioactive pollutants, and would inject the EPA into an area which is the primary responsibility of the NRC--the determination of the safety of levels of abnormal operation.

__Alternative B__: Modify Subpart B of the proposed rule by making the following substitutions:

whole body dose	15	mrem/yr
thyroid dose	45	mrem/yr
other organ doses	15	mrem/yr
krypton-85	25,000	curies
iodine-129	5	millicuries
transuranics	0.5	millicuries

The variance provision would remain in its proposed form; the effective date for implementation of the standards for krypton-85 and iodine-129 would be 1980.

This alternative could be satisfied by all presently proposed sites for which environmental statements have been submitted, with two possible exceptions with respect to the control of iodine emissions. It is also considered quite likely that krypton-85 and iodine-129 control capability can easily be available by the proposed date. The weakness of this alternative is that it would not achieve a significantly greater level of health protection and would at the same time sacrifice flexibility for dealing with the possibility of an unusual site. The earlier effective date for krypton-85 and iodine-129 is not expected to significantly reduce environmental burdens of these materials, since only one or two fuel reprocessing facilities are scheduled to go into operation prior to 1983, and it is anticipated that these will install such systems ahead of schedule for required demonstration and shakedown runs prior to the effective date of the proposed standards in any case.

It is estimated that this alternative would require approximately 0.6 M$/GW(e) in capital costs beyond those required to meet the proposed standards, principally due to increased requirements for iodine control at reactors, and for particulate control at milling operations. No significant improvement in environmental or health impact is anticipated. A significant increase in administrative impact is anticipated, due to the increased difficulty of assuring compliance.

It is concluded that this more restrictive alternative does not offer any significant advantage over the proposed action.

Alternative C: Modify Subpart B of the proposed rule by making the following substitutions:

whole body dose	5	mrem/yr
thyroid dose	15	mrem/yr
other organ doses	5	mrem/yr
krypton-85	5000	curies
iodine-129	1	millicurie
transuranics	0.1	millicuries

The balance of the proposed rule is not altered, including the variance provision.

This alternative would require the incursion of substantial additional costs for minor improvements in the levels of health protection and of environmental burdens of long-lived radionuclides.

The reduction in health effects due to short-lived effluents over that provided by the proposed action would occur primarily at reactors, which contribute 90 percent of the residual impact under the proposed action as shown in Table 10; this improvement would be achieved at a cost approaching one billion dollars per potential health effect removed, a clearly unreasonable burden upon society.

The use of the most effective technology available at all fuel cycle facilities is estimated to cost up to 22 million dollars per gigawatt(electric) of fuel cycle capacity. Up to an estimated total of 160 health effects could be avoided through the year 2000 by installation of such controls at reactors due to reduction of short-lived effluents. The decrease in health impact obtainable through improvement of controls over long-lived materials is not possible to estimate, given the present state of knowledge of performance capability of controls for these materials, but in any case would be less than that for short-lived effluents. The improvement in control achieved for long-lived materials is not easy to estimate since greater uncertainty is not associated with how much control (i.e., how much cost) will be needed to satisfy the requirements of the proposed action, but with what level of effectiveness can be achieved by any of a number of control alternatives of approximately equivalent cost when these systems are placed into operation at commerical facilities. This alternative would impose a large administrative burden on NRC in order to insure compliance with standards set at such low levels.

It is concluded that this alternative, which could impose severe hardships and expense on utilities at some sites while achieving only a small improvement in public health at great cost, would place unreasonable burdens on industry, and therefore on society in general, for insufficient beneficial return.

Table 12 summarizes the differences between these three alternatives and the proposed standards, particularly with respect to health effects, control costs, and control of long-lived radioactive environmental contamination. The table demonstrates that the total reduction in potential health impact of the proposed standards over alternative A is achieved at a present worth cost on the order of one hundred fifty thousand dollars per health effect, while those of alternatives B and C over the proposed standards each require costs of several tens of millions of dollars per health effect. Figure 12 is a reproduction of Figure 3, showing the risk reduction-versus-costs (per gigawatt of electric power capacity for the fuel cycle) for the various controls required to satisfy these alternatives to the proposed action.

TABLE 12

COMPARISON OF THE PROPOSED STANDARDS AND ALTERNATIVE LEVELS OF CONTROL OF ENVIRONMENTAL RELEASES

Action	Health Effects/GW(e)[*†]	Control Cost/GW(e)[**]	Long-Lived Radionuclides Limited (Year)	Variance
Alternative "A"	4.7	6.7 M$	None	No[††]
Proposed Standards	0.92	7.6 M$	^{85}Kr, ^{129}I, Transuranics (1983)	Yes
Alternative "B"	0.88	10.2 M$	^{85}Kr, ^{129}I, Transuranics (1980)[†††]	Yes
Alternative "C"	0.32	22 M$	^{85}Kr, ^{129}I, Transuranics (1983)	Yes

[*] For thirty years operation of typical facilities over the years 1970-2000. See Note †, Table 10.

[**] Present worth, including capital and operating costs for 30 years plant life. See Reference 48.

[†] Excludes carbon-14 and tritium, which are not addressed by any of these alternatives. These two isotopes are estimated to contribute a potential 45 additional health effects, as a result of their 100-year environmental dose commitments, per GW(e) of fuel cycle capacity operated for 30 years.

[††] This alternative is intended as a limit on abnormal emission levels, beyond which shutdown would occur.

[†††] Earlier introduction of controls over long-lived materials under this alternative could result in the elimination of up to an additional 25 potential health effects, worldwide, due to the elimination of the 100-year environmental dose commitment of potential releases from the fuel cycle during 1980-1982.

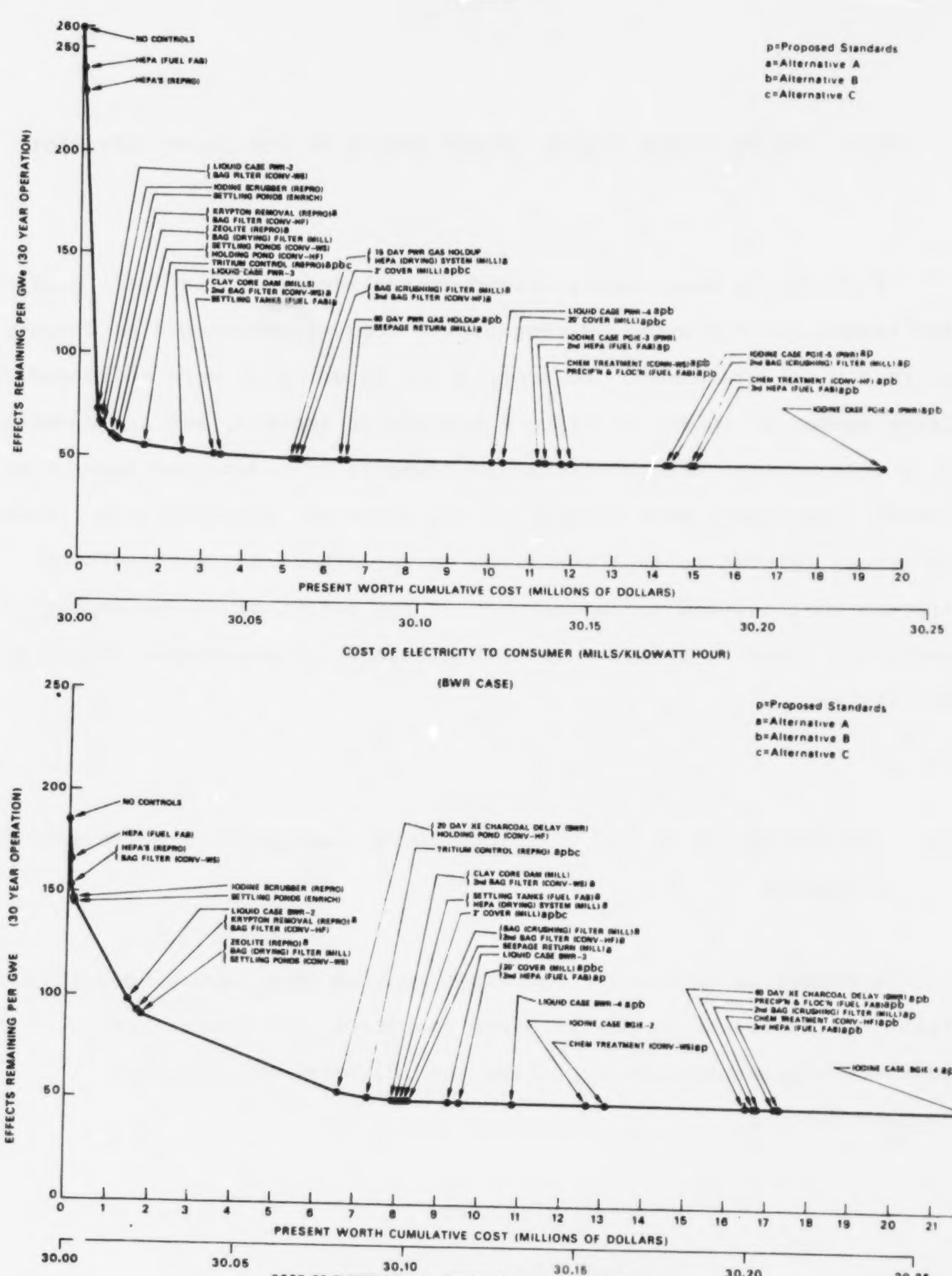

FIGURE 12 . RISK REDUCTION VS. COST FOR THE ALTERNATIVES CONSIDERED. THE SYSTEMS NOT REQUIRED BY THE ALTERNATIVE LIMITS ARE INDICATED BY SYMBOL.

VIII. MAJOR ISSUES RAISED DURING REVIEW OF THE DRAFT STATEMENT

Each of the many issues raised during review of the draft statement are treated in the detailed response to comments contained in Chapter IX of this final statement. However, a few major areas were addressed by a large number of commenters from a variety of aspects, and are deserving of a more unified treatment than is possible in a detailed comment-by-comment response. This chapter of the statement provides such treatment of issues related to implementation of the standards, the costs of krypton control, and the assessment of the potential health impact of radiation doses at levels anticipated beyond the boundaries of nuclear facilities.

A. IMPLEMENTATION OF AND VERIFICATION OF COMPLIANCE WITH THE PROPOSED STANDARDS

A number of commenters expressed concern over issues associated with implementation of the proposed standards (see Chapter IX). Industry representatives expressed the following concerns and recommendations:

1. The UFC Standards, if promulgated by EPA without prior development of detailed procedures for implementation, could have a major disruptive influence on licensing and operation of fuel cycle facilities.

2. Measurement of doses to individuals in the environment at the level of the standards is not practical.

3. An assessment of the cost-effectiveness of the standards cannot be made without guidance on implementation.

4. An interpretation that the variance provision apply only to emergency power situations would result in excessive costs to the public for a negligible return in public health protection.

Recommendations made included the following:

1. Regulatory Guides for implementation should be issued for public review and comment prior to promulgation of the standards. These should include guidance on environmental models, compliance procedures, multiple facilities, and specification of parameters for realistic assessment of doses to individuals.

2. The standards should formally incorporate Appendix I to 10CFR50 as implementation for up to 5 reactors on a site.

These concerns of industry were reinforced by NRC comments, which included:

1. Substantial modifications of the NRC regulatory system would be required; and, in addition, 120 licensing actions would have to be reexamined.

2. Federal Radiation Guidance would require monitoring at 10 percent of the limits set by the standards, and, further, present techniques for environmental monitoring at such levels are inadequate.

3. Costs for compliance would be excessive, particularly since NRC presently has no capability of its own for environmental measurements.

4. The standards would require frequent shutdowns, and use of the variance would not be justified under most situations.

The NRC made no recommendations for implementation.

Environmental groups and the general public expressed concern that the NRC would be lax in its enforcement of the standards, and recommended that EPA carefully specify and monitor implementation of the standard in considerable detail.

The Agency has carefully considered all of the above matters in developing these proposed standards and is confident, after this examination, that these concerns are not warranted. Detailed responses to these specific concerns are provided in Chapter IX. We describe below some general guidelines concerning implementation. However, it remains the Agency's position that detailed implementation is the function of the NRC (within broad guidelines established by EPA regarding the intended application of the standards). This division of responsibility was expressly set forth by the President's message transmitting Reorganization Plan No. 3 of 1970. As the result of NRC and industry comment on the original proposal issued May 29, 1975, it became obvious that more detailed guidance was required than the general statement of position contained in the original proposal. Supplementary information issued January 5, 1976, for use at the public hearings held March 8-10, 1976, contained such an expanded exposition of the Agency's view of appropriate implementation. That exposition contined several major points:

1. Existing NRC models for environmental pathways are, in general, satisfactory to EPA for use in demonstrating routine compliance through the monitoring of effluents.

2. Environmental monitoring should be used to supplement such effluent monitoring in cases of suspected noncompliance.

3. Conformance with Appendix I design objectives was ordinarily sufficient basis for a presumption that any reactor site containing up to 5 units would be able to conform to the standards when in actual operation.

4. In special cases (as at mill tailings) where both environmental and effluent measurements are difficult, compliance should be

demonstrated through the use of operational measures - specifically, stabilization to prevent wind erosion of tailings.

5. Quantity limitations (40CFR190.10(b)) should be implemented through a system of apportionment among the various operations of the fuel cycle, and assignment of required facility effluent stream decontamination factors where appropriate.

6. Use of the variance should be predicated upon a demonstrable public need for power.

In view of the continued expression of concern over implementation issues during the public hearings outlined above, the Agency constituted a task force of experts from its environmental monitoring laboratories, which have been long active in assessments of environmental radiation resulting from releases from fuel cycle facilities, to independently reexamine the feasibility of implementation of the proposed standards. The Agency maintains laboratories in Montgomery, Alabama; Las Vegas, Nevada; and in Cincinnati, Ohio, that each have unique capabilities for monitoring of environmental radioactivity. The conclusions of the task force are summarized below, and in general are consistent with the Agency's previously expressed views on these subjects. In areas where there are differences between task force recommendations and previous Agency policy, these are noted in the discussion below. It should be recognized that these conclusions are intended in the sense of guidance and should not be interpreted as literal dictates of the regulations required to implement these standards. Those regulations will be developed by the NRC, and should be worked out through detailed interaction with the affected components of industry, with timely consultation by NRC with EPA as to the appropriateness of any proposed implementing regulations, particularly in the event that difficulties develop.

A similar situation obtains with respect to verification of compliance. Enforcement authorities reside in NRC, not EPA. EPA expects that the NRC will adequately assure compliance, and EPA's own "compliance" activities will consist principally of the review of the performance, as reported by NRC, of fuel cycle facilities and of any variances permitted by NRC. As required, EPA will provide NRC with guidance on the adequacy of its compliance and variance posture with respect to these environmental standards.

1. Recommendations for Operational Application of the Standards

a. Limits on doses to individuals: Compliance with the dose limits of the standards should be monitored by measuring the quantities of radionuclides discharged in aqueous and gaseous effluents and relating these discharges to the dose commitment rates from all significant pathways to limiting receptors by utilizing methods similar to the Nuclear Regulatory Commission's environmental dose models. The dose commitment rates calculated in this manner should be verified by comparison with those determined through the routine radiological surveillance program.

The task force concluded that NRC models for environmental pathways, as exemplified by Regulatory Guides 1.109 and 1.111, are quite adequate for compliance assessment, although it is recommended that these models be supplemented with site-specific parameters to the maximum feasible extent. Similarly, the task force found that the environmental monitoring programs exemplified by NRC Regulatory Guide 4.8 specify an essentially adequate program regarding both number, type, and locations of monitoring points, and instrumental sensitivities. Finally, the task force recommended the institution of quality assurance programs for both effluent and field monitoring programs.

Conformance to the standards should thus be measured using the most reasonable and, as required, realistic means available. Thus, in the case of dose to the thyroid, measurement of the radioiodine content of milk at the nearest farm, coupled with a determination of the milk consumption habits of the residents, would constitute a reasonable basis for a final determination of noncompliance. Conversely, calculations based on observed releases and meteorology should generally provide the basis for a routine finding of compliance. Sites failing this test would merit progressively more detailed study, leading finally to the above-described (or a comparable) determination of noncompliance (or compliance).

In the case of potential doses to the whole-body and other organs a similar sequence of compliance verification methods is available. The Agency believes that it may be presumed that existing models for calculation of exposure fields due to gaseous and liquid releases, using measured data on quantities released, local meteorology, and stream-flow characteristics, are adequately conservative to serve as the basis for verification of compliance with these standards. If reason exists to believe, based on use of such source term measurements and models, that noncompliance may exist at a particular site, than more detailed field measurements may be employed to verify or disprove the existence of such a situation (or, of course, the facility could reduce its emissions to achieve model-based compliance).

In a very few special situations when two or more sites are in close proximity, it may be necessary for the regulatory agency to make allowance for contributions from several sites in order to assure compliance with the standards at locations intermediate between such sites. For sites as close as a few miles from each other overlapping contributions of as much as 10 to 20% may be possible. The NRC should make the necessary adjustments in the individual technical specifications of facilities at such sites to provide reasonable assurance of compliance. However, in the vast majority of situations the sum of all reasonably possible contributions from all sources other than the immediately adjacent site will be small compared to these standards, and should be ignored in assessing compliance. It would not be reasonable to attempt to incorporate into compliance assessment doses which are small fractions of the uncertainties associated with determination of doses from the primary source of exposure.

A potential difficulty exists regarding implementation of the standards at mill sites. Gamma surveys in the vicinity of some existing mill tailings piles show values ranging up to several hundred mrem/yr in situations where it is logical to assume that these elevated gamma radiation levels are the result of windblown tailings. Although the measurement of 25 mrem/yr increments in such dose rates is possible, rigorous measurement techniques would be required to identify locations where new depositions of windblown particulates elevate pre-existing local levels by 25 mrem/yr. Furthermore, because of the projected 20-year operational lifetime of a typical mill and the assumed additive impact of new depositions, 1/20 of 25 mrem/yr, or approximately one mrem/yr, would have to be measured if the standard were to be implemented by a regulation based on verification on an annual, incremental basis. This would be unreasonable, since one mrem/yr is small compared to uncertainties in natural gamma-ray background levels.

A recent engineering survey report developed for the Nuclear Regulatory Commission (ORNL-TM-4903, Volume 1) (73) provides an estimation of the relative ratio of the respirable particles (<10μm) to larger particles (10-80μm) blown off the tailings beach of a well-managed tailings impoundment system. This ratio averages about one and varies from 0.4 to 1.4 depending on specifics of the milling process and other variables. It can be estimated, therefore, that one millicurie/yr of insoluble 0-10μm particles removed from a typical pile by wind could deliver a dose equivalent of approximately one mrem/yr to the lungs of a person living one kilometer downwind of the pile. At the same time, one millicurie/yr of 10-80μm particles might be deposited in a ring one-half to one and one-half kilometers from a pile, yielding a surface contamination level of about 0.2 nCi/m^2. This would result in a gamma-ray exposure level of about 10μm rem/yr. After 20 years of operations, each contributing to surface contamination at such a rate, this exposure might increase to as much as approximately 0.2 mrem/yr.

Accordingly, the critical exposure pathway for windblown tailings is most likely to be to the lungs through the direct inhalation of radioactive tailings, and if this source of exposure is controlled direct whole-body gamma exposure from windblown tailings will also be controlled to a considerably greater degree.

It does not appear at this time to be practical to measure the annual release of radionuclides from operational tailings piles to the air pathway. However, it is practical and reasonable to reduce these releases to very small values (<1 mCi/yr) by application of control measures that will insure that maximum doses to individuals in the vicinity of tailings piles are well within the standards. These measures include covering of exposed tailings, keeping tailings under water, and spraying any tailings "beaches" that develop with chemical binders to prevent blowing. In practical terms, the standards should be implemented with regard to operational tailings piles by requiring proper and reasonable dust control measures and by permanent stabilization following termination of active milling operations.

It should be noted that the standards apply only to annual doses delivered as the result of discharges of radioactive materials beginning after the effective date. They do not apply to doses resulting from discharges before this date. Decontamination of areas contaminated by windblown tailings from and management of tailings piles on previously abandoned mill sites are not covered by and are therefore not required by this standard.

The task force recommended that doses due to transportation activities associated with the fuel cycle be deleted, due to the difficulty of assuring compliance and the low doses anticipated in any case. The Agency has this recommendation under study. At a fuel reprocessing or a multi-unit reactor site the number of shipments of radioactive materials per year in and out of the site could reach several thousand. However, even for this large of number of shipments, doses to nearby individuals under present Department of Transportation regulations would not reach one mrem/yr, if they are located, on the average, more than a few tens of meters from the shipping route, and if the vehicles involved remain in motion while in the vicinity of the site. Implementation of the standard for transportation would not require, therefore, modification of existing packaging and shielding requirements. It probably would be necessary, however, to require guaranteed non-stop shipments (a service which is presently obtainable from the transportation industry) to avoid buildup of doses to by standards at habitual stopping places, or to provide restricted access areas for layovers, and to make some sort of allocation of the dose limits for application near operating facilities. It should be noted that the standards would not apply to transportation personnel while they are engaged in handling shipments; such exposure is considered to fall in the category of occupational exposure.

b. Limits on quantities of specific radionuclides released: Compliance with the limits on quantities released to the general environment should be monitored by: 1) the establishment by the regulatory agency of the quantities of specific radionuclides covered by the part that may be released to the general environment by each operation of the fuel cycle, based upon a determination of the most economical places in the fuel cycle where effluent reduction may be obtained to satisfy the standards, and 2) licensee monitoring, using effluent and inplant measurements, of the radionuclides discharged and the decontamination factors achieved at those operations where effluent control measures are required to satisfy the standards.

The task force also recommended that effluent control measures should not be required of any fuel cycle operation other than fuel reprocessing, for the radionuclides specified. Implementation of the nuclide-specific limits on releases of long-lived materials thus requires a determination by the NRC of the operating decontamination factors that must be achieved at locations that are the principle potential sources of environmental releases of these materials. In order to make such a determination it would be necessary to characterize before 1983, except in the case of transuranics, the maximum average values of environmental releases of these materials from minor classes of sources to be permitted essentially unrestricted release (e.g., krypton-85, iodine-129, and transuranic releases from power reactors or fuel fabrication facilities). Following this, compliance would consist of verification that the appropriate decontamination factors are being realized through inplant measurements at the principle potential sources regularly reported on a routine basis.

Monitoring of the DF's achieved by inplant control systems for the three types of radionuclides specifically limited by the standards appears to be readily achievable using conventional monitoring techniques and analytical procedures, and such measurements appear to be provided for at the one facility approaching operational status. Flow-through ionization chambers are capable of measurements of krypton-85 at concentratons of less than 1 pCi/cm , a concentration 1000 times lower than that corresponding to the standard for a typical stack effluent volume. Similarly, x-ray spectrometry is capable of sensitivities of the order of 1 pCi for iodine-129; at 10% of the proposed limit a charcoal sample of stack effluent would accumulate, for a 10 minute sample of 0.2% of the stream, 1000 pCi. Finally, gas-flow proportional counters, using 24-hour filter samples (collected on 0.1% of the gas stream) would exhibit detection limits at least 1000 times smaller than activities corresponding to the standard. Periodic confirmation of the isotopic distribution of transuranics would also be necessary.

It should not be necessary to routinely monitor minor releases of these materials from minor classes of sources, once these have been properly characterized as such, unless normal monitoring of general releases discloses that an unusual situation exists which indicates that normal "de minimus" releases of these materials may be being exceeded. Such an occurrence would, presumably, not constitute a "normal" release and investigation and correction would be warranted in any case.

c. The variance provision: Continued noncompliant operation by any licensee should not be permitted for significant periods of time in the absence of a variance. Remedial measures for such noncompliance could include such measures as requirements for corrective or ameliorative measures which will bring the operation into prompt compliance, the assessment of fines, and, ultimately, revocation of the license to operate. In cases where the public interest is served by: a) the need for orderly delivery of power, or b) an acceptable schedule for the timely achievement of compliance capability, a variance may be issued.

The task force also recommended that, in cases of minor noncompliance, a proposed compliance plan which would achieve compliance for the average performance over a three-year period should be automatically considered as serving the public interest, and be an acceptable basis for a variance. They further recommended that variances not be predicated solely on a demonstrated need for the orderly delivery of power. A number of commenters pointed out that such a restriction would not be reasonable. For example, a facility may have installed a control system which, in spite of good faith performance on the part of the supplier and the user, may fail to achieve operational capability on a timely basis, or, once installed may experience operational failure at some time, yet operation of the facility may not be essential to "the orderly delivery of electrical power." The Agency agrees that, although in no case should operation continue if the safety of the operation is compromised, it may easily be the case that only small excursions above these standards would occur in such cases, so that the added risk to the general public would be small in comparison to the economic penalty that would be associated with such operation. For example, it has been estimated that the incremental daily cost of power to replace that supplied by a 1 GW(e) power reactor is on the order of 400 thousand dollars (96). The Agency is considering broadening the variance provision in line with the above recommendations, so that the regulatory agency may, if it deems it to be in the overall societal interest, grant a variance on the basis of an approved plan to achieve compliance in a timely fashion, that is, in the minimum time reasonably achievable given the circumstances of each specific case.

It is not anticipated that utilization of the variance provision based upon a need to insure the orderly delivery of power is likely to be either required or appropriate for any facility other than a power reactor in the near future. That is not to say that it would be inappropriate to use that variance provision if circumstances warranted, but that such circumstances appear unlikely. On the other hand, it is quite possible that a power emergency, either local, regional, or national, could occur, and that continued production of power by a reactor experiencing higher than normal releases would be in the public interest.

In proposing these standards the Agency purposely did not specify detailed procedures to be followed to obtain a variance, since these should be developed by the NRC with opportunity provided for the views of the interested public and the industry to be heard. The Agency does, however, have some general views on the implementation of this provision.

First, the use of the variance should be predicated upon a demonstrable public need for power, or upon demonstration by a licensee that a real need exists and compliance will be achieved on a schedule approved as timely and in the public interest by the regulatory agency. Second, the granting of a variance should be publicly announced and include an assessment of the extent of the excess exposure and releases anticipated, the anticipated schedule for achieving compliance, the reason for the excess release, and the reason for granting the variance. Finally, after the variance has terminated, a final assessment of each of the above factors should be issued promptly.

In general it is anticipated, based upon past experience, that when a facility is approaching a condition in which excessive releases are possible that normal monitoring and reporting of facility releases will provide more than adequate forewarning so as to permit timely consideration of the need for a variance. However, in order to provide for quick response in the case of a sudden power emergency, it may be desirable for the regulatory agency to establish some basic criteria for semi-automatic invocation of a temporary variance under such circumstances. Such criteria would have to be limited, at a minimum, by considerations such as conformance with NRC's safety requirements and Federal Radiation Protection Guides on occupational exposure, limitations which are not affected by these standards.

2. Operational vs. Pre-Operational Application of the Standards

An important consideration relative to these standards is the NRC's continuing development of guidance for design of facility effluent systems and for development of operating technical specifications, codified in 10CFR50, which implements the Federal Radiation Guidance that exposures of the public be maintained as far below the Federal Radiation Guides "as practicable" (25 FR 4402). The Commission has already issued such guidance for single unit light-water-cooled power reactors and has had underway development of similar guidance for fuel reprocessing, milling, and fuel fabrication facilities, although recently doubt as to the likelihood that issuance of such guidance will be considered in the near future has been expressed by the NRC (95). The guidance issued thus far for single unit light-water-cooled reactors appears to provide adequate assurance of compliance with these standards during actual operations (unless the NRC finds that extreme extenuating circumstances exist for a specific site) for sites containing up to at least five such power reactors. (See Section VI-F-1.) Additional guidance may be required in the future, as noted by the Commission in its opinion filed with 10CFR50, Appendix I, for sites containing larger numbers of facilities (50).

These standards will supercede, for the nuclear power industry, the Federal Radiation Guides codified in 10CFR20 as limiting doses to members of the public at unrestricted locations. Just as the development of the guidance expressed by Appendix I to 10CFR50 took place within the limitations specified by those guides, the development of future 10CFR50 design and operating guidance will now take place within the limits specified by these standards. However, it is not anticipated that the disparity between standards and this guidance will, in general (but not always), be nearly so great as formerly. For example, at fuel reprocessing sites, all or most of the thyroid individual dose standard could be taken up by any new 10CFR50 guidance (whereas zero dose may be postulated through liquid pathways due to the absence of any liquid discharges). It is thus not the intent of the Agency that the standards for dose be "apportioned" to various operations of the fuel cycle. They apply equally and in full to doses from any operation or combination of operations in the cycle, and it is not anticipated that significant contributions to doses to any individual from multiple sites will be common. In the few instances where overlap of significance could occur, this should be dealt with on a site-specific basis -- not generically through apportionment.

It is particularly important to recognize that the standards apply only to doses received by individuals and quantities of radioactive materials released to the environment from operating facilities. This situation is in contrast to design guidance set forth, for example, by Appendix I to 10CFR50 for light-water-cooled power reactors, which applies to pre-operational considerations, such as licensing for construction of nuclear facilities. While such guidance is useful for providing the basis for concluding that such facilities can be expected to conform to standards which apply to actual operations, it is not a substitute for such standards. Both the task force and industry expressed considerable concern over the possibility that unnecessarily conservative assumptions at the design stage could lead to implementation that would require greater expenditures for control systems than those intended by EPA in establishing these standards. The Agency agrees that such conservatism is not warranted or intended. It is perhaps natural that such a tendency should have evolved, given previous radiation standards which were more than ten times higher than levels routinely achieved by effluent controls. However, the proposed standards are based on a far more realistic assessment of control capabilities, costs, and benefits, and require an equally realistic implementation.

Consideration of the adequacy of control measures at facilities during pre-operational stages with respect to these standards should be limited to a finding, either for specific sites, or on a generic basis, as appropriate, that the facility has provided or has available to it adequate means to provide reasonable assurance that these standards can be satisfied during actual operations. Such means may include the provision of cleanup controls on discharge streams, the ability to modify in the future, if necessary, its mode of operation to mitigate environmental discharges, or methods which interrupt exposure pathways in the environment. In calculating potential doses to members of the public it is important that realistic models be used, and that unnecessary conservancies common in the past when environmental standards were a factor of twenty or more times higher not be used in assessing the capability of a proposed site to show a reasonable probability of being able to operate in conformance with these standards. Thus, in assessing designs involving multiple units on a single site, realistic consideration should be made of the site size, the locations of individual units relative to limiting receptors, the degree of overlap of independent pathways for limiting receptors, and the stochastic nature of effluent releases from the various units on the site. The important point is that the standards specify maximum doses to real individuals and maximum quantities of certain materials actually delivered or discharged to the environment, not the specific design parameters of individual facilities. Thus, for example, it is the Agency's view that conformance to Appendix I by a planned reactor on a site containing up to five such facilities (unless extremely unusual combinations of liquid and air pathways of exposure are actually present and are expected to be simultaneously intercepted by real individuals) should generally constitute de facto demonstration to the NRC that a reasonable expectation exists that these standards can be satisfied in actual operation. The Agency will, in the course of its continuing review of environmental statements, identify any situations for which it believes that such an expectation has not been adequately justified. A more detailed exposition of some areas meriting in-depth discussion of the Agency's view of an adequate demonstration of reasonable expectation of compliance, such as for adjacent sites, minor releases of specifically limited radionuclides from fuel cycle facilities, doses from windblown material originating from mill sites, and transportation-related doses, has been provided above.

3. Implementing Regulations

A number of regulations or regulatory actions are affected by these standards, as the above discussion of implementation indicates. These include:

a. 10CFR20 - Modify, to reflect where 40CFR190 supercedes for normal releases from uranium fuel cycle operations.

b. 10CFR50, Appendix I - Modify to indicate that additional requirements may be required for sites containing more than five light-water-cooled reactors, or, if the NRC so determines, in other special cases.

c. Review license conditions for fuel cycle facilities, other than light-water-cooled reactors conforming to Appendix I, for conformance to 40CFR190.

d. Determine whether any sites exist which are close enough to other sites to receive substantial contributions to dose from such sites, and make any necessary modifications of technical specifications in such cases (the Point Beach and Kewaunee sites appear to be the only such potential case presently in existence).

e. Determine the apportionment to be made for unrestricted release (relative to 40CFR190) of krypton-85, iodine-129, and alpha-emitting transuranics of half-life greater than one year at fuel cycle facilities not major sources of emissions of these nuclides, and determine the decontamination factors required at major sources.

f. Establish criteria, as required, for granting of variances when this is in the public interest, including reporting requirements for any plan to achieve compliance in a timely manner.

g. Recommend, where necessary, additional requirements on transportation of nuclear wastes and spent fuel to prevent layovers in areas to which public access is possible.

Several regulatory activities already required by existing NRC regulations or underway are also relevant to implementation of these standards. These include:

h. Continuing development of regulatory guidance for fuel cycle activities other than light-water-cooled reactors.

i. Definition of regulatory models for doses to individuals near fuel cycle operations.

j. Definition of "temporary and unusual operating conditions" for implementation of limiting conditions for operation under Appendix I to 10CFR50.

The most significant efforts required, of these that are not already required or committed, are items c., e., f., and g.. These concern directly the implementation of the standards, the balance are either minor codifications of the standards into existing regulations, or represent reflection of the existance of these standards into existing ongoing efforts.

4. EPA Verification of Compliance

The Agency will assess compliance with these standards through its review of NRC implementing regulations, operating data supplied to the NRC by licensees, and any variances issued by NRC. Supporting activities will include the Agency's continuing review of draft and final environmental statements for all fuel cycle facilities, field studies at selected fuel cycle facilities, and assistance to the NRC, when necessary, through field measurements in cases of possible noncompliance.

Under general NEPA and FRC authorities, the Agency routinely reviews and comments on all NRC regulations, including 10CFR50 guidance and regulatory guides, pertaining to environmental releases and exposures of the public due to nuclear fuel cycle operations. In the future, this review will also include consideration of the implementation of these standards. This review will encompass, among others, the appropriateness of design basis assumptions, environmental transport models, dose conversion assumptions, environmental monitoring and reporting requirements, and, finally, operating compliance requirements. The Agency will not, however, routinely review technical specifications or other license requirements pertaining to individual licensees.

The Agency also maintains a continuing review of the state of the environment with respect to contamination by radionuclides and doses to the public, including contributions from fuel cycle sources. Beginning this year, the results of this review will be published annually. This report will depend, for fuel cycle sources, primarily upon data collected by the NRC. The Agency has requested that the NRC supply this information in sufficient detail to permit reasonably detailed annual assessments of the exposures of members of the public and releases to the environment at fuel cycle facilities.

EPA's review of draft and final impact statements for individual fuel cycle facilities will serve to allow EPA to identify to NRC situations in which it believes the capability of the operation to assure future compliance, when the facility is completed, may be questionable. However, such findings will remain advisory, as in the past, since responsibility for compliance with these standards during actual operations rests with the facility and the NRC.

EPA has for some years conducted special field studies in order to characterize the environmental releases, transport, and impact of radionuclides from fuel cycle facilities. These have included detailed general studies at pressurized and boiling water reactors, a fuel reprocessing facility, and at mill tailings piles. In addition, specialized studies of iodine pathways and of nitrogen-16 radiation at reactors have recently been carried out. These studies will continue in the future. They are of invaluable assistance in providing soundly based knowledge for assessing the behavior of environmental releases of radioactive materials, and in judging the adequacy of environmental models used for assessing both general environmental impact and detailed compliance by individual facilities. The measurement capabilities developed for these studies may also prove useful and will be available for situations in which the NRC needs assistance in field verification of compliance.

5. Timing of Implementation of the Standards

It is proposed that these standards become effective two years from the date of promulgation, with the exception of those for krypton-85 and iodine-129, which are proposed to become effective in 1983.

All existing reactors are now or will shortly be in compliance. In any case, it is considered reasonable to expect that any reactor facilities not now in compliance with Appendix I will be by the fall of 1978, over three years after its issuance and the earliest possible implementation date for these standards. The question of timing of implementation of the standards is not significant, therefore, as it applies to reactors.

Only one fuel reprocessing facility is now likely to become operable by 1978, and, on the basis of its environmental statement and EPA's assessment of its projected control capabilities, this facility should be able to achieve compliance with the standards at that time. Future compliance with requirements for krypton and iodine releases will depend on the installation of additional controls by 1983. In this regard, it should be noted that the effective date of 1983 for this portion of the standard applies to any nuclides produced after that date, and not to nuclides produced in fuel irradiated prior to 1983.

Implementation of these standards at milling facilities will in many cases require the installation of updated dust collection equipment, and institution of dust control methods at tailings piles. This equipment is commonly available in commerce. The standards do not apply retroactively to offsite windblown tailings, nor to tailings piles at sites no longer licensed.

B. CONTROL OF KRYPTON-85

The proposed standard limits discharges of krypton-85 from operations in the uranium fuel cycle to 50,000 Ci/GW(e)-yr of power produced. This proposal was based on a variety of considerations which were discussed in the draft statement. Comments questioning this proposed action were received in the following major areas: 1) environmental and health effects models, 2) the availability, cost, and effectiveness of technology, 3) waste storage, and 4) international considerations.

1. Environmental and Health Effects Models

The major question raised concerning the environmental model used was the appropriateness of calculating doses to the world population instead of to the population within 50 miles of the facility or within the borders of the U.S. If population doses are calculated for these more limited areas, the projected health effects committed would, of course, be smaller and the benefit of the proposed standard would be less. It is well known, however, that krypton, a noble gas, distributes rapidly throughout the world's atmosphere and persists in a diluted but uniform concentration for several decades. The Agency believes that the only appropriate basis for evaluating the environmental impact of the release of krypton-85 to the environment is to consider the total population exposed. Since there is no feasible mechanism available to confine krypton-85 releases to areas where they expose only either local populations or U.S. citizens, the only realistic evaluation of the impact of a decision to permit discharge of krypton-85 is to calculate exposure of the world population.

Estimation of potential health effects from krypton-85 based on doses to the world population was based on the assumption of a linear nonthreshold relationship between dose and effects. Several commenters questioned the appropriateness of basing the krypton-85 health effects estimates on the sum of a large number of very low doses delivered at low dose rates. This question apparently is suggestive that these doses, by being small, are inconsequential and ought not to be included in such estimates. Such a suggestion requires the assumption that a threshold exists for radiation effects that lies somewhat above 100 mrem/yr, the average value of background radiation doses to which exposure to krypton is added. The Agency knows of no basis for making such an assumption. Therefore, it has been constrained, in the absence of scientific information to the contrary, to base its estimates of the potential health impact of krypton-85 exposures on the linear nonthreshold model (see Section VIII-C below).

2. Krypton-85 Control Technology

On the basis of questions on the costs, availability, and effectiveness of technology to control krypton-85 control at fuel reprocessing facilities and new information presented at public hearings on these proposed standards, the Agency has reexamined available information on the practicability of providing such control in order to reasonably implement the limit proposed for the uranium fuel cycle. These considerations, which are summarized here, are discussed in more detail in a technical supplement (Part IV) prepared for the Environmental Analysis of the Uranium Fuel Cycle (10).

Three new sources of information or equipment design and costs have become available since the time of the original consideration of these proposed standards. First, the public hearings on the proposed Barnwell Nuclear Fuel Plant (BNFP) during the fall of 1975 developed extensive information on system design and costs, some of which has been further updated in comments to the Agency on the proposed standard. Second, the Exxon Nuclear Corporation has developed a design for a 2100-ton per year plant (initial start-up to be 1500 ton per year) which includes a conceptual design for controlling krypton-85 in the dissolver offgas. Third, a system to control krypton-85 has been ordered for the Tokai-Mura fuel plant, a 215 ton per year plant currently in advanced stages of construction in Japan. The system is being provided by a U.S. company (the Air Reduction Corporation) and indications are that the system will be installed and undergoing cold testing by early 1977.

The Agency has discussed the technology and economics of krypton control with equipment vendors, visited all national laboratories where krypton control is being developed or applied, and has discussed detailed aspects of krypton control with experts knowledgeable in the techniques of fuel reprocessing. From this study, it has become clear that the cryogenic distillation approach to krypton control is much closer to application than the flurocarbon absorption system. The system ordered for the Tokai-Mura fuel plant utilizes cryogenic distillation to separate krypton-85. The fluorocarbon absorption process is still undergoing development at the Oak Ridge

Gaseous Diffusion Plant and will not be ready for testing with radioactive materials until 1980. Both systems are expected to exhibit in-plant decontamination factors of greater than 100.

The most detailed and reliable cost estimates for krypton-85 control are available for the cryogenic distillation process. Cost estimates provided by commenters were for the Barnwell Nuclear Fuel Plant. These estimates ranged up to 43.5 million dollars (including an escalation cost of 12.5 million dollars) for removing krypton-85 by cryogenic distillation from a dissolver offgas stream of 550 scfm. The Barnwell plant was not designed to minimize the cost of installing krypton control (although provision was made to retrofit such control, if it should be required); thus, the offgas flow rate and the resultant costs of the treatment system are rather high. On the other hand, the conceptual design of the proposed Exxon plant, which assumes krypton control will be installed, has an offgas flow rate of 25 scfm.

The volume of offgas to be treated has a large impact on the cost of systems required to provide krypton control; thus, the Agency has based its primary consideration of the cost of krypton-85 control on a cryogenic distillation unit for a future-generation generic plant with offgas flow rates similar to that of the proposed Exxon plant. In order to provide some convervatism, costs were estimated for flow rates of 100 scfm and 50 scfm. These costs and the associated reduction in potential health effects and population dose are shown in Table 13. The Agency's

TABLE 13

COST-EFFECTIVENESS OF KRYPTON CONTROL AT FUEL REPROCESSING PLANTS

Plant Design	Total Present Worth ($1,000)	Population Dose Averted (man-kilorem)			Health Effects Averted	$/Man-Rem Averted			$/H.E. Averted
		Whole Body	Gonads	Lungs		Whole Body	Gonads	Lungs	
Generic Designs[*]									
50 SCFM	18,200	187	249	374	140	52	26	5	130,000
100 SCFM	24,100	187	249	374	140	69	35	7	170,000
"Barnwell" Designs[**]									
Partially Redundant	38,300	131	178	267	100	157	77	15	380,000
Fully Redundant[***]	44,600	141	188	282	105	169	85	17	425,000

[*] 2100 MTHM per year (the design capacity of the proposed Exxon facility, which projects an offgas flow rate of 25 scfm).

[**] 1500 MTHM per year; 550 scfm is the reported maximum offgas flow rate for Barnwell (see text).

[***] Affidavit of James A. Buckham, April 2, 1976, submitted with supplemental submission of Allied-General Nuclear Services in connection with EPA's public hearings March 8-10, 1976, on Environmental Radiation Protection Standards for Nuclear Power Operations.

estimated costs for retrofitting the BNFP are also included in Table 13. In calculating the number of potential health effects and the population doses averted, it was assumed that the cryogenic system would operate 90 percent of the time needed at a decontamination factor of 100 (i.e., 99% removal). Of the total number of potential health effects estimated, 60 percent result from whole-body dose, 25 percent from gonadal dose, and 15 percent from lung dose. This breakdown was used to determine the fraction of the total krypton control cost spent to avert whole-body, gonadal, and lung doses to the population. The costs per man-rem for each of these types of dose are small fractions of the interim value of $1,000 per man-rem to the whole body or thyroid used by NRC to evaluate the cost-effectiveness of controls for reactors.

Table 12 also contains estimates of the cost effectiveness of reducing potential health effects. These costs are $130,000 to $170,000 per effect averted for the generic design. A retrofit of the Barnwell plant would, according to EPA's estimate, result in reductions of potential health effects at a cost of about $380,000 per effect averted; for the fully redundant system cost estimate provided by the plant operator, the cost per health effect averted is $425,000. The criterion (Chapter V) used by the Agency to judge whether expenditures for reducing health effects are reasonable (i.e., that the cost be less than about $500K/health effect) is therefore satisfied. The costs for health effect prevention for the generic plant are even more reasonable.

The Agency has chosen the generic plant designed for krypton-85 removal as the most appropriate basis for considering control costs. This choice was made because the significant impact on both the environment and the costs of producing nuclear power will be in the large amount of fuel reprocessing capacity that will have to be provided in future years if the fuel cycle is to be operated so as to provide recovery and recycle of fissile uranium and, possibly, plutonium. For this reason, the Barnwell facility should be considered as a special, first-of-a-kind case with unique control cost requirements. The cost estimates provided to date for this facility are considered to be higher than should be expected for future plants because they are based on considerable degree of redundancy, a very high offgas flow rate, and do not appear to reflect a systems analysis of the plant to optimize costs associated with krypton control. If the offgas flow rate were reduced by half, the total costs of krypton control would be reduced by about 30-40 percent. Various alternatives and tradeoffs might be considered for reducing the offgas flow rate, with potential overall reduction in current cost estimates for BNFP. For example, design changes in the dissolver could reduce in-leakage, use of nitrogen or some other gas instead of air may reduce recombiner requirements, and the air flow through the treatment system may be reduceable by recycle of the main offgas stream and use of a bleeder system for effluent control.

Although krypton-85 control systems are judged to be cost-effective in reducing potential health effects, it is also appropriate to consider the effect of such control on the overall cost of generating electricity. A generic-size fuel recovery plant can process annual discharges of fuel from 65-70 reactors producing one GW(e)-yr of electricity; thus, the cost of fuel recovery is a very small percentage of total power cost. Inclusion of krypton-85 control at fuel reprocessing plants would increase the commercial cost of power (estimated to be about 40 mills per kwh) by less than 0.1%. Future fuel recovery plants are expected to be of even larger capacity which would further lower the overall effect of such controls on total power costs. It is important also to recognize that the energy and economic value of recovering fissile material has increased considerably in recent years as the cost of providing new uranium for fuel has escalated. This trend has made the uranium present in unprocessed fuel an important energy resource that has considerable market value to the nuclear power industry. This has recently been confirmed by a study by the Allied-General Nuclear Service Company (74) of the recovery part of the fuel cycle. Not only is the value of fuel recovery taking on new importance but the industry should be increasingly able to provide for the cost of controls within the normal course of doing business.

The availability of krypton control systems is, as pointed out by several commenters, an important consideration. The various components of systems that would likely be used are readily available; however, total systems have not been installed or tested. This was accounted for in the proposed standard by setting an effective date of

1983. The several vendors who have done further design work continue to show a willingness to bid and quarantee systems based on a cryogenic distillation process. Various studies under ERDA contracts and the system being provided for the Tokai Mura plant should provide sufficient information on total system performance to allow achievement of the proposed effective date, even with any design adjustments that may be required as a result of initial performance. A similar commitment to install and test a system for a U.S. plant could also be reasonably carried out within this time frame.

3. Waste Gas Storage

Several comments were received concerning the additive costs of storing recovered krypton-85. The systems costs discussed above contain facilities for two-year on-site storage prior to processing and shipment to a central repository. The incremental costs associated with krypton storage at such a repository would not be expected to exceed those inherent in the storage of other wastes associated with uranium fuel cycle operations.

In this regard, ERDA contractors are presently evaluating a variety of methods for krypton waste storage. Particular attention is being given to storage in pressurized cylinders for several decades and to confinement in a solid matrix such as sodalite which, if it can be made insoluble, would offer certain safety advantages for shipment and storage since the waste material would be at atmospheric pressure.

4. International Considerations

Several countries are committed to the use of an ever-increasing amount of nuclear power in order to meet their needs for electrical power. Each of these expansions in nuclear electrical power generation add to the amount of krypton-85 available for atmospheric release and its associated worldwide impact. Although the U.S. is currently the leading nation in nuclear power generation, its contribution of krypton-85 to the world's atmosphere can be projected to be overshadowed by that from other nations before the end of the century. Such a circumstance raises the question of whether the U.S. should require krypton-85 control from the uranium fuel cycle operations in the absence of similar commitments by other leading nuclear power generating countries.

It is the view of the Agency that krypton-85 from nuclear electrical power generation should be controlled by all major countries and that as the acknowledged world leader in the development of nuclear power it has a responsibility to provide leadership, as it has in development of nuclear energy itself, for controlling adverse impacts on the environment and the public. This responsibility exists for localized effects as well as those which distribute and persist so as to affect large populations. Setting an appropriate example is basic to providing such leadership.

In summary, the Agency has concluded that krypton-85 should be controlled at the level proposed in the draft statement. This conclusion is based on a reevaluation of the costs, availability, and effectiveness of control systems balanced against the Agency's responsibility to ensure that the world's atmosphere is not degraded by introducing krypton-85 into it with its potential health impact on the world population for several decades, and its unknown potential for altering atmospheric properties and behavior. The systems for such control are in various stages of testing or application in the U.S. and Japan and are expected to be available at a reasonable cost per effect averted by the effective data of the standard. Both the effective date and the fraction of removal required have been chosen to provide reasonable leeway for the provision of adequate protection systems to eliminate this public health problem within a responsible time frame.

C. HEALTH EFFECTS ESTIMATES

Potential health effects associated with radiation doses have been estimated for this statement by use of the linear nonthreshold model for radiation carcinogenesis and the application of risk coefficients derived from the report of the Committee of the National Academy of Sciences on the Biological Effects of Ionizing Radiation (NAS-BEIR) (14). Reasons for using a linear nonthreshold dose response relationship have been set forth in a previously published policy statement on the relationship between radiation dose and effects assumed by the Agency for the purpose of establishing standards to protect public health (April 3, 1975), which is reprinted here as Appendix B. In formulating this policy, the Agency has recognized that much of the data base used in the NAS-BEIR Report was obtained at higher doses and dose rates than those likely to be encountered under environmental conditions, and that this may lead to risk estimates which either over or under estimate the incidence of radiation induced effects on health (9). The Agency does not, however, believe that sufficient information is currently at hand to justify either a reduction or an increase in the NAS-BEIR estimates of the health risk from ionizing radiation.

Comments were received reflecting many different points of view on health effects issues. One group agreed that the linear nonthreshold model using NAS-BEIR risk coefficients is appropriate for estimating radiation risks due to effluents from the uranium fuel cycle. Another believed this model was not sufficiently conservative to either protect public health or provide a proper basis for cost-risk balancing, while a third group believed the the National Academy of Sciences' estimates of health risk are too conservative at low doses and dose rates. Frequent reference was made to a statement in a recent report of the National Council on Radiation Protection and Measurements (75) that extrapolation from the rising portion of dose-incidence curves derived from data obtained at high doses and dose rates cannot be expected to provide realistic estimates of the actual risk of cancer from low level doses of low linear energy transfer (LET) radiation. In addition, reference was made to the recently published Reactor Safety Study (76) which made numerical estimates of reduced effects at low dose rates and the suggestion was made that dose-rate effectiveness factors (DREF) of less than one be utilized in the EPA analysis to show fewer health effects than would be estimated on the basis of the NAS-BEIR report. The Reactor Safety Study applied a DREF of 0.2 at low doses and dose rates.

The basis for suggestions that a DREF be applied in making estimates of the potential impact of ionizing radiation is centered around the hypothesis that for low dose rate, low LET radiations the initial injury is usually repairable and that at low dose rates time is available for this biological repair to occur. This is in contrast to high LET particles where the amount of energy transferred locally is so large that a critical site is assumed to be damaged beyond repair.

Dose rate effects are often observed after acute, low LET exposures where immediate survival is the end point of interest. Such studies often show reduced effects at low dose rates, and their observation may or may not also be accompanied by significant departure from a linear dose-effect relationship. Caution is required however, in translating these well-known radiation injury studies, where cellular depletion and survival studies demonstrate that biological repair occurs, to the case of radiation carcinogenesis. Considering the lack of knowledge of basic mechanisms for radiocarcinogenesis, conservatism in assuming the efficacy of repair mechanisms for unidentified initial injuries would appear to be warranted.

The Reactor Safety Study (76) assumed that it is possible to quantify the role that repair processes may play in reducing cancer risk due to low dose rate, low LET radiation. The primary reference cited for this viewpoint is a paper by Mays, Lloyd, and Marshall (77), who on the basis of their review of the literature on cancer and leukemia in relation to low and high dose rate exposures, claim an average DREF of 0.2 applies to low dose-rate exposures. There are several reasons, as outlined below, for believing that the scientific foundation for this reduction factor is to weak to allow its application as a basis for standards to provide public health protection. The analysis fails to differentiate between studies employing chronic irradiation at low dose rates, the case of interest here, and studies where a fractionated dose was delivered at high dose rates intermittently over a relatively long test period. Health effects following fractionated patterns of irradiation are a function of two competing factors in addition to the direct radiocarcinogenic potential of the primary insult. The number of cells at risk to subsequent exposure may be reduced due to cell death and, in addition the immune response may be augmented or impaired. These effects have been shown to have a profound effect on radiocarcinogenicity and careful experimentation and use of controls is required to sort out the role of these factors in the analysis of results (78). Until the experiments cited in reference 77 have been replicated with controls for such effects their interpretation is unclear, particularly since many of these experiments were not designed to test for dose rate effects, but were performed for other reasons.

Experiments with both short-lived species (rodents) and dogs were examined by Mays, et al., for the effect of dose rate on radiocarcinogenesis. In the case of dogs, the only long-lived species considered, life shortening was used as a surrogate for radiation carcinogenesis. The analysis compared two dog experiments which were performed at different times, in different laboratories, and by different investigators. There was no attempt to control the experiments so as to obtain relevance between them. In particular, the fractionation of the exposures, the housing of the animals and the sex of the dogs irradiated differed. It is also likely that the patterns of carcinogenesis were quite different for reasons other than dose-rate effects, since the low dose rate experiment (79) was designed to observe changes in spermatogenesis while the high dose rate experiment (80) was performed with female dogs for which a principal end-point, mammary cancer, resulted in either death or surgical intervention. In the former experiment, the low dose rate males were, of course, not at risk for this hazard. Mays, et al., calculated life shortening per rad for low dose rate (0.06 - 0.6 r/day) exposure of males dogs and compared this parameter to that obtained with the female dogs irradiated at 8 rad per minute, and concluded that the efficacy of the higher dose rate was about 12 times that of the lower. In view of the differences between the two studies, this conclusion is unwarranted. It is of interest, however, that there was no significant change in either the average or median age of death for the male dogs as a function of dose rate. This is illustrated in Table I, below, taken directly from the cited work (79). It would appear that either the dose-rate effectiveness factor was infinite or the experiment, which was designed to test for sterility, was not sensitive enough to be useful for examining another endpoint, premature death. In view of the small number of dogs involved (Table I) EPA believes the latter interpretation of the results is preferable and that this data for long-lived species does not support the hypothesis of reduced radiocarcinogenesis at low dose rates.

Table I

Daily Dose* R/day	No. of Dogs	Average Age at Death (Y)	Median Age at Death (Y)
0	20	12.97	13.14
0.06	20	13.76	14.06
0.12	10	13.21	13.78
0.60	10	12.33	12.67

*Given in a 10 minute period.

Mays, et al. (77), also referenced studies with rodents by Shellabarger and Brown (81); Mole (82); Grahn, Fry and Lea (83); and Upton, Randolph, and Conklin (84). In contrast to the studies with long-lived species these papers provide DREF values of approximately 0.23-1.0; 0.14; 0.19; 0.08, 0.45, 0.14, 0.26 and 0.1; respectively.

While these DREF values do suggest that in most of these cases animal experiments indicate radiocarcinogenesis is less at low dose rates, the admonitions of Upton, et al. (84,85), concerning the interpretation of data on radiocarcinogenesis and life shortening in mice, should be considered also. That is, the effects of both "wasted" radiation and age-specific modulation of radiation sensitivity must be allowed for in the interpretation of such experiments. Indeed, the paper by Mole (82) cited by Mays, et al., illustrates this point. He shows that the length of time over which fractionated doses are delivered is an important factor in determining the resultant carcinogenicity and that in some cases long exposure periods lead to higher, not lower, cancer incidence.

It is also important to note that the effect of dose rate on radiocarcinogenesis in animals is not likely to provide an adequate predictor for the pattern of human cancer risk, since the incidence of naturally occurring cancer, life span and the sites of cancer induction following irradiation differ in man and in animals. In experiments involving radiation-induced cancers in inbred strains of laboratory animals, it must be recognized that the genetic characteristics of the strain are imposed on the results. In the case of human populations, the cancers observed following radiation are in part related to the carcinogens in the environment as well as genetic characteristics. While the relative importance of these two factors cannot be weighted properly today, it is unreasonable to assume that general patterns of radiation induced cancer in inbred mouse strains are directly applicable to the heterogenous human population.

The degree to which NAS-BEIR Committee risk estimates might over or under estimate radiation risk has been reviewed by the Agency in light of NCRP pronouncements (75) on models of radiation injury. There is growing evidence, as suggested in NCRP #43, that the Kellerer-Rossi model for initial radiation injury (not radiocarcinogenesis *per se*), which predicts a summation of linear and dose squared response, is useful for interpreting at least some radiation effects data. However, experimental measurements of energy transfer as function of site size and the available biological data in support of this model indicate that the dose at which the linear, not the dose squared, term dominates the predicted response is dependent on the spatial distribution of low LET radiation (86) and therefore is likely to vary with the end point considered. Experimental analyses indicate that for genetic effects linearity dominates for doses less than 100 rad (87), while in the case of some cancers (e.g., adenomas in mice) linearity has been observed at doses as high as 750 rad (88). The range of linearity for some radiogenic human cancers induced by low LET radiation appears to be in excess of several hundred rads (14) but, in general, is unknown. Unless all radiogenic cancers are due to energy transfer in sites of the same effective diameter, the dose at which the cancer response departs from linearity will be, according to the Kellerer-Rossi theory, quite variable, since for low LET radiations specific energy is a very sensitive function of site diameter. The difference between 100 and 750 rad cited above corresponds to less than a factor of three in site diameter. Contrary to the position of many critics of the BEIR Report, the Kellerer-Rossis theory would seem to indicate that at doses below a hundred rads or so the frequency of initial injury would be nearly proportional to dose, not dose squared.

One hundred rad is about the low end of the range of data considered by the BEIR Committee in making their estimates of cancer risk (14). Since, in general, the BEIR Committee interpolated linearly between zero and the lowest dose level where excess cancer was observed, it is unlikely their risk estimates were heavily biased by a dose response that varied by the square of the dose and hence over predicted the number of radiogenic cancers, as suggested in NCRP #43. In a few cases it is possible to test for this effect directly by comparing the results of human experience at high and low doses. Comparisons of the incidence of both breast cancer and thyroid cancer at high and low dose levels indicates there is little or no difference in the number of excess cancers per rem (89). Rather than argue that thyroid and breast cancer are unrepresentative of radiogenic cancers in man, and therefore exceptions to an apparent recovery from precancerous radiation damage observed in rodents, it would appear more prudent and indeed advisable to limit exceptions to the NAS-BEIR risk estimates to those human cancers where supporting epidemiological data is available.

The Agency is aware that research in this area is very active at present and that ongoing studies may result in improved risk evaluations. However, at this time specific DREF values for chronic low dose rate, low LET radiations have only been proposed by ad hoc groups. No recognized standards-setting body has utilized such data in the establishment of radiation protection standards or guides. At present, the Agency considers an allowance for reduced injury due to low dose rates too speculative to be made part of the basis for standards developed to protect public health. While the Agency does not rule out the possibility that such data may become available in the future, it does not believe sufficient data exists now to warrant a revision of the health effect estimates given in this statement.

In contrast to the comments received that the EPA health effects estimates were too conservative, other commenters believed some risks had been seriously underestimated. Dr. Ernest Sternglass has presented the hypothesis that, at low dose rates, low LET radiation is much more likely to cause injury for a given dose than at high dose rates. The Agency did not find the materials presented in support of the inverse dose rate hypothesis persuasive. While it has been demonstrated that lipid bilayers manufactured in the laboratory are susceptible to increased radiation damage at low dose rates, these artificial membranes are unlike mammalian cell membranes. No evidence was presented for a causal relationship between radiation effects on artifical membranes and the health impact hypothesized by Dr. Sternglass. The essential concept, relating the chemical experiments on artifical lipid membranes to living organisms, is not demonstrated in Dr. Sternglass' testimony or in the references he cites. The testimony asserted that at low dose rates the concentration of the superoxide radical, a hypothesized agent of radiation injury, was enhanced. However, the role of the superoxide radical in radiation injury has not been demonstrated. Contrary to the experiments cited by Dr. Sternglass, in other reported work (90) the presumed absence of superoxide in E. coli. did not affect the sensitivity of these cells to radiation, a result that is consistent with the proposition that this radical is not involved in the mechanism of the oxygen effect.

The proposed extension of the inverse membrane theory to human health is even less convincing. Two studies were cited: one in Oslo with rats where many of the changes seen at low doses and dose rates were not statistically significant (91); and a second study by Scott, et al., on radiation workers (92). Dr. Sternglass alleges that Scott's investigations showed evidence for erythrocyte membrane permeability following low doses (at occupational exposure levels). However, permeability is apparently not involved, as Scott points out. Rather, his results show a greater ^{86}Rb uptake, i.e., an active process not related to membrane rupture.

Even if it were assumed that indirect damage to cell membranes is enhanced at low dose rates, an assumption which has not been proven, the relationship of membrane damage to cancer has not been established. It has also not been shown that immune response mechanisms are impaired at the dose levels that are of concern for the uranium fuel cycle standards, 25 mrem annually. Observed effects on immune systems occur after doses of 25 rems (93), a factor of 1000 higher. Nor is there epidemiological data in support of the view that an enhanced cancer risk results from low dose-rate irradiations. The data on vital statistics supplied are not proof of cause and effect or, in the Agency's judgment, even a demonstration of a reasonable cause of concern. For example, in the case of Japanese studies for childhood cancer cited by Dr. Sternglass, a change in the basis for reporting cancer rates in Japan in 1950 is the cause for most of the effects attributed to radiation (94).

Dr. Sternglass' theories are original, and to insure that new ideas are not neglected, the Agency has followed his analyses for a number of years. However, it has been unable to identify either a supported sequence of ideas in his arguments or other responsible researchers on radiation injury who find similar interpretations of the extensive radiation effects data in the scientific literature. The Agency has concluded that his testimony on health effects at low dose rates is not a sufficient basis for revising the estimates given in this statement.

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APPENDIX

ENVIRONMENTAL PROTECTION AGENCY

[40 CFR Part 190]

ENVIRONMENTAL RADIATION PROTECTION
FOR NUCLEAR POWER OPERATIONS

Notice of Proposed Rulemaking

Reorganization Plan No. 3, which became effective on December 2, 1970, transferred to the Administrator of the Environmental Protection Agency the functions of the former Atomic Energy Commission to establish "...generally applicable environmental standards for the protection of the general environment from radioactive material." The Plan defined these standards as "limits on radiation exposures or levels, or concentrations or quantities of radioactive material outside the boundaries of locations under the control of persons possessing or using radioactive material." On May 10, 1974, the Agency published an advance notice of its intent to propose standards under this authority for the uranium fuel cycle and invited public participation in the formulation of this proposed rule.

The Agency has reviewed and considered the comments received in response to that notice and proposes herein environmental radiation standards which would assure protection of the general public from unnecessary radiation exposures and radioactive materials in the general environment resulting from the normal operations of facilities comprising the uranium fuel cycle. Nuclear power generation based on recycled plutonium or on thorium is excluded from these standards because sufficient operating data and experience concerning fuel cycles utilizing these fuels are not yet available. Before any of these developing technologies becomes of potential significance to public health the need for additional generally applicable standards will be considered.

The environmental radiation standards proposed in this notice supplement existing Federal Radiation Protection Guidance limiting maximum exposure of the general public [F.R. Docs. 60-4539 and 61-9402] by providing more explicit public health and environmental protection from potential effects of radioactive effluents from the uranium fuel cycle during normal operation. Numerically the proposed standards are below current Federal Radiation Protection Guides. The Agency is not, at this time, proposing revisions in existing Federal Radiation Protection Guidance for the general public because of its belief that a detailed examination of each major activity contributing to public radiation exposure is required before revision of this general guidance should be considered. Existing Federal Radiation Protection Guidance for workers in the fuel cycle is also not affected by these proposed standards. In addition, since these standards are proposed under authority derived from the Atomic Energy Act of 1954, as amended, they do not apply to radioactive materials and exposures in the general environment that are the result of effluents from mining operations because that Act does not provide authority over such effluents. Finally, since there are no planned releases from existing radioactive waste disposal sites and these sites primarily serve sources of waste other than uranium fuel cycle operations, these standards do not apply to such sites. The Agency has each of these areas of concern under continuing study.

It is the intent of the Agency to maintain a continuing review of the appropriateness of these environmental radiation standards and to formally review them at least every five years, and to revise them, if necessary, on the basis of information that develops in the interval.

INTERAGENCY RELATIONSHIPS. Reorganization Plan No. 3 transferred to the Environmental Protection Agency (EPA) the broad guidance responsibilities of the former Federal Radiation Council and also transferred from the former Atomic Energy Commission (AEC) the more explicit responsibility to establish generally applicable radiation standards for the environment. However, the responsibility for the implementation and enforcement of both this guidance and these standards lies, in most cases, in agencies other than EPA as a part of their normal regulatory functions. For nuclear power operations, this responsibility, which had been vested in the AEC, is now vested in the Nuclear Regulatory Commission (NRC), which will exercise the responsibility for implementation of these generally applicable standards through the issuance and enforcement of regulations, regulatory guides, licenses, and other requirements for individual facilities.

BASIC CONSIDERATIONS. The Agency has concluded that environmental radiation standards for nuclear power industry operations should include consideration of: 1) the total radiation dose to populations, 2) the maximum dose to individuals, 3) the risk of health effects attributable to these doses, including the future risks arising from the release of long-lived radionuclides to the environment, and 4) the effectiveness and costs of the technology available to mitigate these risks through effluent control. The Agency also recognizes the findings of the recent study of the biological effects of low levels of ionizing radiation by the Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR Committee) of the National Academy of Sciences - National Research Council. Two of the principal conclusions of the BEIR Committee were: 1) that current societal needs appear to be achievable "...with far lower average exposure and lower genetic and somatic risk than permitted by the current Radiation Protection Guide. [Thus,] to this extent, the current Guide is unnecessarily high..." and 2) that "Guidance for the nuclear power industry should be established on the basis of cost-benefit analysis, particularly taking into account the total biological and environmental risks of the various options available and the cost-effectiveness of reducing these risks."

For the purpose of setting radiation protection standards the most prudent basis for relating radiation dose to its possible impact on public health continues to be to assume that a potential for health effects due to ionizing radiation exists at all levels of exposure and that at the low levels of exposure characteristic of environmental levels of radiation the number of these effects will be directly proportional to the dose of radiation received (a linear non-threshold dose-effect relationship). Even under these assumptions, the range of estimates of the health risks associated with a given level of exposure derived from existing scientific data is broad. It is recognized that sufficient data are not now available to either prove or disprove these assumptions, nor is there any reasonable prospect of demonstrating their validity at the low levels of expected exposure with any high degree of certainty. However, the Agency believes that acceptance of the above prudent assumptions, even with the existence of large uncertainties, provides a sound basis for developing environmental radiation standards which provide reasonable protection of the public health and do so in a manner most meaningful for public understanding of the potential impact of the nuclear power industry. Standards developed on this basis are believed to also protect the overall ecosystem, since there is no evidence that there is any biological species sensitive enough to warrant a greater level of protection than that adequate for man.

Radiological protection of the public from nuclear power industry operations has been based to date on guidance which has had as its primary focus the general limitation of dose to the most exposed individual, rather than limitation of the total population dose from any specific type of activity. The proposed expanded development of the nuclear power industry requires, however, the use of a broader environmental perspective that more specifically considers the potential radiological impact on human populations of radioactive effluents from this industry, rather than just that on the most exposed individual. A number of long-lived radionuclides are now discharged from various fuel cycle operations which carry a potential for buildup of environmental levels and irreversible commitments for exposure of populations that may persist for tens, hundreds, or thousands of years. The extent of the cumulative population doses which may occur over the years following release of such radionuclides is related to their radioactive decay times, the details of their dispersion through environmental media, the period over which they remain in the biosphere, and their exposure (both internal and external) of individuals in populations. The cumulative dose resulting from releases to the environment of such materials can be termed an "environmental dose commitment," and quantitatively expressed in terms of the number of person-rems of dose commited. The proposed standards are based, to the extent that present knowledge permits, on such projections of the migration of radioactive effluents through the biosphere and estimates of the sum of potential doses to present and future populations during that migration.

Since potential effects from radiation exposure are assumed to occur at any level of exposure, it is not possible to specify solely on a health basis an acceptable level of radiation exposure for either individuals or populations; it is necessary to balance the health risks associated with any level of exposure against the costs of achieving that level. In developing the proposed standards, EPA has carefully considered, in addition to potential health effects, the available information on the effectiveness and costs of various means of reducing radioactive effluents, and therefore potential health effects, from fuel cycle operations. This consideration has included the findings of the AEC and the NRC with respect to practicability of effluent controls, as well as EPA's own continuing cognizance of the development, operating experience, and costs of control technology. Such an examination made it possible to propose the standards at levels consistent with the capabilities of control technology and at a cost judged by the Agency to be acceptable to society, as well as reasonable for the risk reduction achieved. Thus, the standards generally represent the lowest radiation levels at which the Agency has determined that the costs of control are justified by the reduction in health risk. The Agency has selected the cost-effectiveness approach as that best designed to strike a balance between the need to reduce health risks to the general population and the need for nuclear power. Such a balance is necessary in part because there is no sure way to guarantee absolute protection of public health from the effects of a non-threshold pollutant, such as radiation, other than by prohibiting outright any emissions. The Agency believes that such a course would not be in the best interests of society.

The total population impact associated with a particular level of effluent control is best assessed in terms of dose commitments to populations measured in person-rems, which are then converted into estimates of potential health impact. However, the environmental models used for deriving these assessments, while useful for making estimates of potential health impact, are not considered to be so well-defined as to allow standards for populations to be expressed directly in terms requiring their explicit use. The Agency believes that future changes and refinements in models, and thus in the person-rem assessments upon which these standards are based, will occur on a continuing basis. The standards are therefore not proposed directly in terms of person-rems, but future reviews of their adequacy will reflect any changes in model-based assessments of population dose. Standards have also not been proposed directly in terms of person-rems because the regulatory implementation of such a requirement does not appear to be administratively feasible for the fuel cycle under existing widely varying geophysical and demographic conditions and for doses that may, in some instances, be delivered over indeterminately long periods of time. The proposed standards are expressed in terms of 1) limits on individual doses to members of the public and 2) on quantities of certain long-lived radioactive materials in the general environment. On the basis of its assessments of the health risks associated with projected annual population doses and environmental dose commitments, the Agency has concluded that these two types of standards are the most appropriate choice of criteria to provide effective limitation of the potential health impact on populations of short-lived and long-lived radioactive materials, respectively.

Even though adequate protection of populations considered as a whole may be assured by standards based upon the above consideration of health risks and control costs, it may not always be the case that adequate protection is assured on this basis to some individuals in these populations who reside close to the site boundaries of nuclear facilities, because of the distribution characteristics of certain effluents. Such a situation is possible in the case of thyroid doses due to releases of radioiodines from reactors and fuel reprocessing facilities. Although the risk from such doses to nearby individuals is quite small, it is inequitable to permit doses to specific individuals that may be substantially higher than those to other members of the population from other radionuclides. Additional protection for these individuals should be provided when technology or other procedures are available for minimizing any additional potential risk at a reasonable cost. The standards proposed to limit doses to individuals reflect this additional requirement where it is appropriate to do so.

TECHNICAL CONSIDERATIONS. It is convenient to consider effects of radioactive materials introduced into the environment by the uranium fuel cycle in three categories. Prior to the occurrence of nuclear fission at the reactor only naturally occurring radioactive materials are present in fuel cycle operations. This first category of materials consists principally of uranium, thorium, radium, and radon with its daughter products. Radioactive materials introduced to the environment from facilities for milling, chemical conversion, isotopic enrichment, and fabrication of fuel from uranium which has not been recycled are limited to these naturally occurring radionuclides. As a result of the power-producing fission process at the reactor a large number of new radionuclides are created as fission or activation products. These may be introduced into the general environment principally by reactors or at fuel reprocessing and are conveniently categorized as either long-lived or short-lived fission and activation products, depending upon whether their half-lives are greater than or less than one year. Although naturally occurring radionuclides are of some concern, it is these fission and activation products which are of greatest concern from the point of view of controlling radiation doses to the public due to nuclear power operations.

Standards are proposed for the fuel cycle in two major categories. The proposed standards would limit: 1) the annual dose equivalent to the whole body to 25 millirems, to the thyroid to 75 millirems, and to any other organ to 25 millirems; and 2) the quantities of krypton-85, iodine-129, and certain long-lived transuranic radionuclides released to the environment per gigawatt-year of power produced by the entire fuel cycle to 50,000 curies, 5 millicuries, and 0.5 millicuries, respectively. The first standards are designed to limit population and individual exposures near fuel cycle operations due to short-lived fission-produced materials and naturally occurring materials, and due to transportation of any radioactive materials, while the second specifically addresses potential population exposure and buildup of environmental burdens of long-lived materials.

The proposed standard for annual whole body dose to any individual limits the combined internal and external dose equivalent from gaseous and liquid effluents as well as exposure to gamma and neutron radiation originating from all operations of the fuel cycle to 25 millirems. Such a limit is readily satisfied at all sites for which fuel cycle facilities are presently projected through the year 1985 (including any potential overlap of doses from adjacent sites) by levels of control that are cost-effective for the reduction of potential risk achieved; is in accord with the capabilities of controls anticipated by the AEC for all sites for which Environmental Statements have been filed; and, on the basis of present operating experience at existing sites, can be readily achieved in practice. The combined effect of any combinations of operations at the same location that are foreseeable for the next decade or so was also examined and is judged to be small, so that the proposed standards can readily be satisfied by use of levels of control that are similar to those required for single operations. It should be noted that this proposed standard for maximum whole body dose, which is higher than that proposed by the AEC as guidance for design objectives for light-water-cooled reactors, differs from those objectives in that it applies to the total dose received from the fuel cycle as a whole and from all pathways, including gamma radiation from onsite locations. It is also not a design objective, but a standard which limits doses to the public under conditions of actual normal operation.

The appropriate level for a standard limiting the maximum annual total dose to the thyroid of individuals is not easy to determine. A standard for maximum total thyroid dose based on considerations limited to the same criteria as for maximum whole body dose (cost-effectiveness of reduction of total population impact and achievability) would permit unacceptably high doses to individuals near some site boundaries. The proposed standard of 75 millirems per year to the thyroid has therefore been chosen to reflect a level of biological risk comparable, to the extent that current capability for risk estimation permits, to that represented by the standard for dose to the whole body. The effluent controls required to achieve this limit have been examined extensively by EPA, AEC, and the industry, particularly in regard to the AEC's proposed Appendix I to 10 CFR 50 for light-water-cooled reactors, and, in the view of the Agency, this level of maximum annual individual dose to the thyroid can be achieved at reasonable effort and cost.

The principal potential doses to internal organs other than the thyroid are to the lung via inhalation of airborne particulates and to bone due to ingestion via water and other pathways of the naturally occurring materials processed in the several components of the fuel cycle required to convert uranium ore into reactor fuel. The impact on populations due to effluents from these operations is generally quite small (due to their predominately remote locations and lack of widespread dispersion), however, significant lung doses are possible to individuals near to these operations, particularly in the case of mills and conversion facilities. The use of well-established, efficient, and inexpensive technology for the retention and control of particulate effluents can readily achieve the levels of control required to meet the proposed standard of 25 millirems per year for limiting dose equivalent to the internal organs (other than thyroid) of individuals.

Environmental radiation exposures from transportation operations are due to direct radiation. Although average radiation doses to individuals in the general public from transportation activities are very small, situations in which individuals could receive higher doses may reasonably be postulated. It is recognized that exposures due to transportation of radioactive materials are difficult to assess and regulate because as shipments move in general commerce between sites the exposed population is constantly changing. Transportation activities should be conducted with every effort made to maintain doses to individuals as low as reasonably achievable, consistent with technical and economic feasibility. In any case, the maximum dose to any member of the general public due to uranium fuel cycle operations, including those due to shipments of radioactive materials, should not exceed the proposed standard of 25 millirems per year to the whole body of an individual. The Agency will continue to examine potential exposures due to transportation of radioactive materials with a view to further action, if necessary.

Among the variety of long-lived radionuclides produced in the fuel cycle, tritium, carbon-14, krypton-85, iodine-129, plutonium, and certain other long-lived transuranic radionuclides are of particular significance as environmental pollutants. Environmental pathways of tritium, carbon-14, and krypton-85 are worldwide. Even though the balance of the above radionuclides may not rapidly become widely dispersed, they are significant because of their potential for extreme persistence in environmental pathways, possibly for thousands of years for plutonium and other transuranics, and for even longer periods for iodine-129.

Because of their high toxicity and long half-lives, the cumulative impact of releases of plutonium and other transuranics to the environment could be large. However, due to very large uncertainties concerning their environmental behavior over long periods of time, as well as a lack of definitive information concerning the relationship between exposure to these materials and health effects, the limits of this potential impact cannot be more than roughly estimated. Therefore prudence dictates that the environmental burden of these materials be minimized to the lowest levels reasonably achievable. Similarly, although its toxicity is less than that of the alpha-emitting transuranics, in view of the extreme persistence of iodine-129 (half-life 17 million years) and great uncertainty concerning its environmental behavior, environmental releases of this isotope should be also maintained at the lowest level reasonably achievable. The prevention of unlimited discharges of krypton-85 to the environment from fuel cycle operations is of high priority because of its potential for significant long-term public health impact over the entire world. Finally, carbon-14 and tritium, both of which rapidly enter worldwide pathways as gaseous radioactive materials, are of particular concern because carbon and hydrogen are principal constituents of the chemical structures of all life forms.

These long-lived radionuclides should only be discharged to the environment after careful consideration of the tradeoffs between the societal benefits of the power generated, the current and projected health risks to populations, and the costs and effectiveness of methods available to limit their release. Since the anticipated maximum dose to any single individual from any of these materials is very small, the primary concern is the cumulative risk to population groups over long periods of time. For this reason, it is not of primary importance where or when in the fuel cycle any such materials are released, since the committed impact will be similar. What is important is to assure that any permitted discharge has been offset by a beneficial product, i.e., a quantity of electricity, and that every reasonable effort has been made to minimize it. It is also important to assure that society is not burdened with unreasonable expenditures to minimize these risks in order to gain the necessary benefits of electric power. Fortunately the vast majority of potential health effects due to release of these radionuclides can be avoided at a reasonable cost. The Agency estimates the cost of implementing the proposed standards for these long-lived radioactive materials to be less than $100,000 per potential case of cancer, leukemia, or serious genetic effect averted (less than $75 per person-rem). In view of the above considerations, the Agency believes that the proposed standards, which limit the number of curies of certain of these radionuclides released to the general environment for each gigawatt-year of electricity produced by the fuel cycle, represent the most reasonable means of providing required protection of the general environment for present and future generations. The standards will assure that any environmental burdens of long-lived radioactive materials accumulate only as the necessary result of the generation of an offsetting quantity of electrical energy.

The proposed standards for long-lived materials fall into two categories: those which can be achieved using currently available methods for control of environmental releases, and those that require use of methods that have been demonstrated on a laboratory or larger scale, but have not yet achieved routine use. In the former case, exemplified by the standard of 0.5 millicuries per gigawatt-year for plutonium and other long-lived alpha-emitting transuranics, the standard limits the environmental burden to the lowest level reasonably achievable using currently available control methods. In the latter case, that of the proposed standard of 50,000 curies per gigawatt-year for krypton-85 and 5 millicuries per gigawatt-year for iodine-129, these limiting levels of environmental burdens are not those achievable by best demonstrated performance, but instead by minimum performance reasonably anticipated from introduction of these new systems into commercial operations. As experience is gained with the ability of the industry to limit fuel cycle releases of these materials to the environment, it may be appropriate to reconsider the standards limiting the maximum environmental burdens of these particular radionuclides.

Similarly, as knowledge becomes available concerning the practicability of limiting environmental releases of tritium and carbon-14, the appropriate levels of maximum environmental burdens of these radionuclides due to fuel cycle operations will be carefully considered by the Agency. However, the knowledge base now available is inadequate for such a determination, and no standards are presently proposed for these radionuclides. The potential for a long-term impact due to carbon-14 released from fuel cycle operations was not recognized until the Agency considered environmental dose commitments from the industry in the course of developing these standards; thus consideration of methods for limiting its release to the general environment are only now beginning. Tritium levels in the general environment from fuel cycle operations are not expected to become significant until the late 1980's, and development programs are in existence for control of releases of this radionuclide from its principal source, fuel reprocessing operations. The Agency believes that the development and installation of controls to minimize environmental burdens of both carbon-14 and tritium are important objectives, and will carefully follow the development of new knowledge concerning both the impact and controllability of these radionuclides.

To allow adequate time for implementing the standards for krypton-85 and iodine-129 control, including the necessary testing and analysis required prior to licensing of these control systems, the effective date is proposed as January 1, 1983. Implementation by this date would result in control of these releases before any substantial potential health impact from these materials due to uranium fuel cycle operations can occur and would, in the judgment of the Agency, provide adequate protection of public health thereafter.

The proposed standard for maximum dose to organs excludes radon and its daughter products. Radon is released as a short-lived (3.8 days half-life) inert gas, mainly from tailings piles at mills, and produces its principal potential impact through deposition of its daughter products in the lung. There exists considerable uncertainty about the public health impact of existing levels of radon in the atmosphere, as well as over the best method for management of new sources of radon created by man's activities, which remove this naturally occurring material and its precursors from beneath the earth's protective crust. Radon levels in the general environment are substantial and are dominated by natural sources, except in the immediate vicinity of man-made sources. Exposures from radon and its daughters have previously been the subject of Federal Radiation Protection Guidance, in the case of underground uranium miners (F.R. Doc. 71-7210 and F.R. Doc. 71-9697), and of guidance from the Surgeon General, in the case of public exposure due to the use of uranium mill tailings in or under structures occupied by members of the general public ("Use of Uranium Mill Tailings for Construction Purposes," Hearings before the Subcommittee on Raw Materials of the Joint Committee on Atomic Energy, October 28 - 29, 1971, pp.226-233). The Agency has concluded that the problems associated with radon emissions are sufficiently different from those of other radioactive materials associated with the fuel cycle to warrant separate consideration, and has underway an independent assessment of man-made sources of radon emissions and their management.

IMPLEMENTATION OF THE STANDARDS. These proposed standards are expected to be implemented for the various components of the uranium fuel cycle, operating under normal conditions, by the Nuclear Regulatory Commission. The mechanisms by which these standards are achieved will be a matter between the NRC and the industries that are licensed to carry out various uranium fuel cycle operations, but, in general, will be based on regulations and guides for the design and operation of the various facilities. The Agency is confident that these proposed standards can be effectively implemented by such procedures.

Current rules and regulations applicable to fuel cycle operations generally contain provisions which have the effect of limiting doses to individuals, thus implementation of the proposed standards for maximum doses to individuals should be straightforward. Protection of the public from the environmental accumulation of long-lived radioactive materials may require some changes in regulatory requirements. For example, this standard limits environmental accumulations of certain radionuclides associated with the generation of a gigawatt-year of electrical energy, which is generated only at the power reactor. Since other operations in the cycle which do not generate power are more likely to discharge such materials, it may be necessary for the regulatory agency to make an appropriate allocation to each facility and to determine the emission rates required to satisfy the standard for the entire fuel cycle. This is especially the case for a radionuclide like krypton-85 which can be released either at reactors, during fuel storage, or during fuel reprocessing. The standards do not specify the time, location, or concentration of emissions of long-lived radionuclides. Once a given quantity of electrical power has been generated the specified amount of the radionuclide may be released at any time and at any rate or location that does not exceed the individual dose limitations. Demonstration of compliance with the standard requires only that the total quantity of electricity generated after the effective date of the standards be recorded to determine the maximum quantity of these long-lived radionuclides that may eventually be released.

The Agency recognizes that implementation of the standards for krypton-85 and iodine-129 by the proposed effective date of January 1, 1983, will require successful demonstration of control technology for commercial use that is now in advanced stages of development. The Agency, as stated above, intends to review all of these standards in at least five year intervals. If substantial difficulty should develop for implementing the standards for krypton-85 and iodine-129 with respect to the proposed levels, facility safety, or cost, the Agency will give these factors careful and appropriate consideration prior to the effective date.

With respect to operations associated with the supply of electrical power it is important not only to set standards which will provide satisfactory public health protection, consistent with technical and economic feasibility, but also to minimize societal impacts which may occur as the result of temporary interruptions in those fuel cycle operations that are necessary to assure the orderly delivery of electric power. Such a two-fold objective requires consideration of the question whether to impose stricter standards which achieve lower levels of radiation exposure and environmental burdens of long-lived radioactive materials, but which may force temporary shutdowns which may not be justified on a risk-benefit basis for such periods; or to establish more liberal standards which decrease the possibility of such shutdowns, but may be overly permissive with respect to public exposure and long-term environmental releases. The Agency has attempted to avoid this dilemma by proposing standards that are not permissive with respect to either public exposures or long-term environmental releases and at the same time providing a variance which allows the standards to be temporarily exceeded under unusual conditions. The use of such variances by the regulatory agency will depend to a large degree upon their value judgments concerning the necessity of the fuel cycle operation concerned to a region, overall facility safety, and the possible impact on public health. The proposed variance provides that temporary increases above the standards for normal operations are allowable when the public interest is served, such as to maintain a dependable source of continuous power or during a power crisis. The Agency anticipates that the need to use such variances will be infrequent and of short duration, and that the overall impact on population and individual radiation doses from the operations of the entire fuel cycle will be minimal.

With respect to regulatory implementation of the flexibility provided by this proposed variance provision, the Agency has carefully examined the guidance for design objectives and limiting conditions for operation of light-water-cooled nuclear power reactors as set forth recently by the NRC in Appendix I to 10 CFR 50. It is the view of the Agency that this guidance for reactors will provide an appropriate and satisfactory implementation of these proposed environmental radiation standards for the uranium fuel cycle with respect to light-water-cooled nuclear reactors utilizing uranium fuel. The various monitoring and reporting procedures required by the AEC in the past and supplemented by Appendix I are expected to provide continuing information sufficient to determine that these standards are being satisfied during the course of normal operations of the fuel cycle.

Although the Agency has attempted to limit the effect of radioactive discharges from the fuel cycle on populations and on individuals through these proposed standards, it has not attempted to specify constraints on the selection of sites for fuel cycle facilities, even though the Agency recognizes that siting is an important factor which affects the potential health impact of most planned releases from operations in the fuel cycle. The standards were developed, however, on the assumption that sound siting practices will continue to be promoted as in the past and that facility planners will utilize remote sites with low population densities to the maximum extent feasible.

The Agency has also considered the need for special provisions for single sites containing large numbers of facilities, of single or mixed types, as exemplified by the "nuclear park" concept. Present construction projections by utilities indicate that no such sites are likely to be operational during the next ten years. In view of the need to accumulate operating experience for the new large individual facilities now under construction and the intent of the Agency to review these standards at reasonable intervals in the future, it is considered premature and unnecessary to predicate these standards on any siting configurations postulated for the next decade and beyond. The Agency will consider changes in these standards based on such considerations when they are needed and justified by experience.

It is the conclusion of the Agency that implementation of the proposed standards for normal operations of the nuclear power industry based on the uranium fuel cycle will provide society protection of its environment and the health of its citizens and that this protection is obtained without placing unreasonable financial burdens upon society. In this context, these standards are responsive to the President's energy messages of June 4, 1971, and April 18, 1973, which challenged the Nation to the twin objectives of developing sufficient new energy resources while providing adequate protection for public health and the environment.

REQUEST FOR COMMENTS. Notice is hereby given that pursuant to the Atomic Energy Act of 1954, as amended, and Reorganization Plan No. 3 of 1970 (F.R. Doc. 70-13374), adoption of Part 190 of Title 40 of the Code of Federal Regulations is proposed as set forth below. All interested persons who wish to submit comments or suggestions in connection with this proposed rulemaking are invited to send them to the Director, Criteria and Standards Division (AW-560), Office of Radiation Programs, Environmental Protection Agency, Washington, D.C. 20460, within 60 days after publication of this notice in the *Federal Register*. Within this same time period, interested parties are also invited to indicate their desire to participate in a public hearing on the proposed rulemaking to be scheduled after the comment period ends. Comments and suggestions received after the 60-day comment period will be considered if it is practical to do so, but such assurance can only be given for comments filed within the period specified. Single copies of a Draft Environmental Statement for the proposed standards and a technical report entitled "Environmental Analysis of the Uranium Fuel Cycle" are available upon request at the above address. The above-mentioned technical documents and comments received in response to this notice, as well as comments received in response to the Agency's advance notice of this proposed rulemaking published on May 10, 1974, and the Agency's response to these comments, constitute part of the background for this rulemaking and may be examined in the Agency's Freedom of Information Office, 401 M Street, S.W., Washington, D.C. 20460.

DATED:

Russell E. Train
Administrator

ENVIRONMENTAL RADIATION PROTECTION STANDARDS FOR NORMAL OPERATIONS OF ACTIVITIES IN THE URANIUM FUEL CYCLE

A new Part 190 is proposed to be added to Title 40, Code of Federal Regulations, as follows:

PART 190 - ENVIRONMENTAL RADIATION PROTECTION STANDARDS FOR NUCLEAR POWER OPERATIONS

SUBPART A - GENERAL PROVISIONS

190.01 Applicability

The provisions of this Part apply to radiation doses received by members of the public in the general environment and to radioactive materials introduced into the general environment as the result of operations which are part of a nuclear fuel cycle.

190.02 Definitions

a) "Nuclear fuel cycle" means the operations defined to be associated with the production of electrical power for public use by any fuel cycle through utilization of nuclear energy.

b) "Uranium fuel cycle" means all facilities conducting the operations of milling of uranium ore, chemical conversion of uranium, isotopic enrichment of uranium, fabrication of uranium fuel, generation of electricity by a light-water-cooled nuclear power plant using uranium fuel, reprocessing of spent uranium fuel, and transportation of any radioactive material in support of these operations, to the extent that these support commercial electrical power production utilizing nuclear energy, but excludes mining operations and the reuse of recovered non-uranium fissile products of the cycle.

c) "General environment" means the total terrestrial, atmospheric and aquatic environments outside sites upon which any operation which is part of a nuclear fuel cycle is conducted.

d) "Site" means any location, contained within a boundary across which ingress or egress of members of the general public is controlled by the person conducting activities therein, on which is conducted one or more operations covered by this Part.

e) "Radiation" means any or all of the following: alpha, beta, gamma, or x rays; neutrons; and high-energy electrons, protons, or other atomic particles; but not sound or radio waves, nor visible, infrared, or ultraviolet light.

f) "Radioactive material" means any material which emits radiation.

g) "Uranium ore" is any ore which contains one-twentieth of one percent (0.05%) or more of uranium by weight.

h) "Curie" (Ci) means that quantity of radioactive material producing 37 billion nuclear transformations per second. (One millicurie (mCi) = 0.001 Ci.)

i) "Dose equivalent" means the product of absorbed dose and appropriate factors to account for differences in biological effectiveness due to the quality of radiation and its spatial distribution in the body. The unit of dose equivalent is the "rem." (One millirem (mrem) = 0.001 rem.)

j) "Organ" means any human organ exclusive of the dermis, the epidermis, or the cornea.

k) "Gigawatt-year" refers to the quantity of electrical energy produced at the busbar of a generating station. A gigawatt is equal to one billion watts. A gigawatt-year is equivalent to the amount of energy output represented by an average electric power level of one gigawatt sustained for one year.

l) "Member of the public" means any individual that can receive a radiation dose in the general environment, whether he may or may not also be exposed to radiation in an occupation associated with a nuclear fuel cycle. However, an individual is not considered a member of the public during any period in which he is engaged in carrying out any operation which is part of a nuclear fuel cycle.

m) "Regulatory agency" means the government agency responsible for issuing regulations governing the use of sources of radiation or radioactive materials or emissions therefrom and carrying out inspection and enforcement activities to assure compliance with such regulations.

SUBPART B - ENVIRONMENTAL STANDARDS FOR THE URANIUM FUEL CYCLE

190.10 Standards for Normal Operations

a) The annual dose equivalent shall not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public as the result of exposures to planned discharges of radioactive materials, radon and its daughters excepted, to the general environment from uranium fuel cycle operations and radiation from these operations.

b) The total quantity of radioactive materials entering the general environment from the entire uranium fuel cycle, per gigawatt-year of electrical energy produced by the fuel cycle, shall contain less than 50,000 curies of krypton-85, 5 millicuries of iodine-129, and 0.5 millicuries combined of plutonium-239 and other alpha-emitting transuranic radionuclides with half-lifes greater than one year.

190.11 Variance for Unusual Operations

The standards specified in Paragraph 190.10 may be exceeded if:

a) The regulatory agency has granted a variance based upon its determination that a temporary and unusual operating condition exists and continued operation is necessary to protect the overall societal interest with respect to the orderly delivery of electrical power, and

b) Information delineating the nature and basis of the variance is made a matter of public record.

190.12 Effective Date

a) The standards in this Subpart, excepting those for krypton-85 and iodine-129, shall be effective 24 months from the promulgation date of this rule.

b) The standards for krypton-85 and iodine-129 shall be effective January 1, 1983.

POLICY STATEMENT

Relationship Between Radiation Dose and Effect

Office of Radiation Programs
Office of Air and Waste Management
U.S. Environmental Protection Agency
Washington, D. C. 20460

ISSUED: March 3, 1975

EPA Policy Statement on Relationship Between Radiation Dose and Effect

The actions taken by the Environmental Protection Agency to protect public health and the environment require that the impacts of contaminants in the environment or released into the environment be prudently examined. When these contaminants are radioactive materials and ionizing radiation, the most important impacts are those ultimately affecting human health. Therefore, the Agency believes that the public interest is best served by the Agency providing its best scientific estimates of such impacts in terms of potential ill health.

To provide such estimates, it is necessary that judgments be made which relate the presence of ionizing radiation or radioactive materials in the environment, i.e., potential exposure, to the intake of radioactive materials in the body, to the absorption of energy from the ionizing radiation of different qualities, and finally to the potential effects on human health. In many situations the levels of ionizing radiation or radioactive materials in the environment may be measured directly, but the determination of resultant radiation doses to humans and their susceptible tissues is generally derived from pathway and metabolic models and calculations of energy absorbed. It is also necessary to formulate the relationships between radiation dose and effects; relationships derived primarily from human epidemiological studies but also reflective of extensive research utilizing animals and other biological systems.

Although much is known about radiation dose-effect relationships at high levels of dose, a great deal of uncertainty exists when high level dose-effect relationships are extrapolated to lower levels of dose, particularly when given at low dose rates. These uncertainties in the relationships between dose received and effect produced are recognized to relate, among many factors, to differences in quality and type of radiation, total dose, dose distribution, dose rate, and radiosensitivity, including repair mechanisms, sex, variations in age, organ, and state of health. These factors involve complex mechanisms of interaction among biological chemical, and physical systems, the study of which is part of the continuing endeavor to acquire new scientific knowledge.

Because of these many uncertainties, it is necessary to rely upon the considered judgments of experts on the biological effects of ionizing radiation. These findings are well-documented in publications by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the National Academy of Sciences (NAS), the International Commission on Radiological Protection (ICRP), and the National Council on Radiation Protection and Measurements (NCRP), and have been used by the Agency in formulating a policy on relationship between radiation dose and effect.

It is the present policy of the Environmental Protection Agency to assume a linear, nonthreshold relationship between the magnitude of the radiation dose received at environmental levels of exposure and ill health produced as a means to estimate the potential health impact of actions it takes in developing radiation protection as expressed in criteria, guides, or standards. This policy is adopted in conformity with the generally accepted assumption that there is some potential ill health attributable to any exposure to ionizing radiation and that the magnitude of this potential ill health is directly proportional to the magnitude of the dose received.

In adopting this general policy, the Agency recognizes the inherent uncertainties that exist in estimating health impact at the low levels of exposure and exposure rates expected to be present in the environment due to human activities, and that at these levels the actual health impact will not be distinguishable from natural occurrences of ill health, either statistically or in the forms of ill health present. Also, at these very low levels, meaningful epidemiological studies to prove or disprove this relationship are difficult, if not practically impossible, to conduct. However, whenever new information is forthcoming, this policy will be reviewed and updated as necessary.

It is to be emphasized that this policy has been established for the purpose of estimating the potential human health impact of Agency actions regarding radiation protection, and that such estimates do not necessarily constitute identifiable health consequences. Further, the Agency implementation of this policy to estimate potential human health effects presupposes the premise that, for the same dose, potential radiation effects in other constituents of the biosphere will be no greater. It is generally accepted that such constituents are no more radiosensitive than humans. The Agency believes the policy to be a prudent one.

In estimating potential health effects it is important to recognize that the exposures to be usually experienced by the public will be annual doses that are small fractions of natural background radiation to at most a few times this level. Within the U.S. the natural background radiation dose equivalent varies geographically between 40 to 300 mrem per year. Over such a relatively small range of dose, any deviations from dose-effect linearity would not be expected to significantly affect actions taken by the Agency, unless a dose-effect threshold exists.

While the utilization of a linear, nonthreshold relationship is useful as a generally applicable policy for assessment of radiation effects, it is also EPA's policy in specific situations to utilize the best available detailed scientific knowledge in estimating health impact when such information is available for specific types of radiation, conditions of exposure, and recipients of the exposure. In such situations, estimates may or may not be based on the assumptions of linearity and a nonthreshold dose. In any case, the assumptions will be stated explicitly in any EPA radiation protection actions.

The linear hypothesis by itself precludes the development of acceptable levels of risk based solely on health considerations. Therefore, in establishing radiation protection positions, the Agency will weigh not only the health impact, but also social, economic, and other considerations associated with the activities addressed.